EPIGAEA REPENS IN INDIANA:

HABITAT ASSOCIATIONS AND THE EFFECTS OF CONTROLLED BURNING

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EPIGAEA REPENS IN INDIANA: HABITAT ASSOCIATIONS AND THE EFFECTS OF CONTROLLED BURNING

by

Roger Beckman

ABSTRACT: *As Epigaea repens L. (trailing arbutus) is a rare plant in Indiana, I studied four sites in south-central Indiana to identify habitat requirements and to locate additional sites. Habitat factors studied included soil type, companion vegetation, litter exposure, slope, O horizon depth, aspect, canopy cover, and pH. Epigaea repens is mostly found with litter exposure between 30-60%, slopes of 20-30°, O horizon 1.5-2.0 cm deep, an aspect between 180° (south) and 330° (northwest), canopy cover > 70%, low sapling density (0 to 0.12 saplings/m^2), and a mean soil pH of 3.5. A controlled burn of 15 test plots was done to determine response to fire and litter removal. Flowering 13.5 months after the burn indicated that the burn had a significant negative effect. Seventeen and 1/2 months after the burn, a census of leaves, buds and stems indicated that the burn portions of the plots fared worse than the buffer or control portions. Twenty-five and 1/2 months after the burn the mean number of blossoms was still lower on the burn portions but it was not statistically significant. Sex ratios from three populations were measured for an indication of colony isolation and environmental conditions. All of the populations were slightly female biased. Competition with Vaccinium pallidum, a common companion species, may help restrict E. repens. Sites without E. repens but where the pH is suitable and where Vaccinium pallidum occurs were examined to help determine whether the distribution of E. repens is caused by historic accident or local habitat factors. The future outlook for the persistence of E. repens is positive. Suggestions for a management plan are (1) to locate additional sites, (2) to avoid timber harvesting near present sites in Morgan-Monroe State Forest and (3) to avoid burning as a management tool.*

INTRODUCTION

This study focuses on *Epigaea repens*, a rare species in Indiana, and hence of interest to the Indiana Division of Nature Preserves. My primary objectives are to characterize the habitat requirements of *E. repens* in south-central Indiana and to evaluate controlled burning as a management tool. Such information is essential to develop sound conservation strategies for the species.

Epigaea repens, the trailing arbutus, Mayflower, or ground laurel, is a member of the family *Ericaceae*. It is found in eastern North America from southern Manitoba (ca. 54° N), Nova Scotia, and Quebec south to Florida (ca. 30° N), and Mississippi (Gleason & Cronquist, 1991; Scoggan, 1979; Wood, 1961) (Figure 1). Its abundance varies from area to area. In Maine, New Hampshire, Massachusetts, Connecticut, Pennsylvania, and Virginia it occurs in almost every county. In other areas it is not widespread but still common (e.g. Nova Scotia, North Carolina, Michigan and Minnesota (Roland, 1960; Radford, *et al.*, 1968; Voss, in press; Ownbey & Morley, 1991). In areas such as Florida it is considered rare, occurring only in Escambia, Okaloosa and Liberty counties (Clewell, 1985).

Epigaea repens is an evergreen, decumbent shrub (Clay, 1983) found on sandy or rocky acidic soils (Gleason &

Cronquist, 1991) and occasionally in dry pine forests or along margins of sphagnum bogs (Lakela, 1965). In New England, Councilman (1923) found it more commonly at forest edges, alongside forest roads or in young second-growth pine forests in partial sun. It often occurs in association with other Ericaceous taxa.

It is a shrub with prostrate stems in which the woody stems readily form new roots when soil conditions are favorable (Foster & Foster, 1990). It is dioecious and exhibits stylar polymorphism (Clay, 1981). Flowering occurs in the spring from buds that formed the previous year. The pollinators are various flying insects and ants (Clay, 1983). *Epigaea repens* is the only member of the Ericaceae that exhibits myrmecochory (dispersal of seeds by ants) (Clay, 1983). Birds and snails also consume its fruits and disperse its seeds (Everett, 1980). The species does not transplant easily because it lacks root hairs and is obligately mycorrhizal (Wood, 1961).

Its status in states adjacent to Indiana varies considerably. For example, there is only one old record from Illinois, probably from near Lake Michigan (Swink and Wilhelm, 1979). In Ohio it is listed as frequent in the eastern half of the state (Kellerman, 1893) and common in the dry woods and hemlock slopes of the glaciated Allegheny plateau region (Andreas, 1989). In Kentucky, it is usually found in acidic, sandy soil and mor (i.e. raw) humus in oak and conifer woods in 21 counties (Braun, 1943). In Michigan it is rare in the south, frequent in the central part and common northward. It is found on the borders of marshes and woods in sandy soil (Beal, 1904).

Epigaea repens is rare in Indiana (Deam, 1984; Rabinowitz, 1981). It occurs locally in relatively small populations in a narrow range of habitats in isolated localities, mostly in south-central Indiana and around Lake Michigan (Figure 2 and Table 1).

The official status of *E. repens* in Indiana has been changed in the last five years. In 1979 (Bacone and Hedge, 1979) it was listed as a threatened species. Its status was changed in 1990 to rare (Indiana Dept.of Natural Resources, 1990). Its designation was downgraded to a watchlist status in June 1993 in part because of the discovery of new sites in Morgan-Monroe State Forest and near Lake Monroe (Huffman, pers. comm.).

In south-central Indiana the trailing arbutus is typically found near the top of west-facing dry to dry-mesic forested slopes of deep ravines along or just above the sharp break of the slope. The soils are usually shallow with the bedrock close to the surface. Typically the overstory includes *Quercus* and *Fagus* and the understory contains *Vaccinium*, *Gaylussacia*, *Smilax* and *Carex*. It is likely that *E. repens* is found mainly on steep slopes because in such sites the leaf litter doesn't accumulate and thus bury the recumbent plants (Clay, pers. comm.).

This background information helped me select what information would be important for the management of *E. repens* in Indiana. An understanding of its habitat requirements would reveal which variables should be maintained and which altered to insure its long-term survival.

I analyzed (1) associated vegetation, (2) soil type and depth, (3) pH, (4) litter depth, (5) slope aspect, (6) canopy cover, and (7) hydrological and geological factors in order to characterize habitat requirements. I also analyzed habitat conditions in seemingly appropriate sites where no *E. repens* occurred. In such sites I studied the role of soil pH and the role of *Vaccinium* competition.

There is evidence that burning and disturbance is beneficial to some Ericaceous species (Parsons, 1989) and they often form a highly flammable shrub layer that promotes fire. Fire can stimulate growth, open up new habitat (Plocher and Carvell, 1987), release nutrients (Oosting, 1956) and remove inhibiting chemicals from the soil surface (Crawley, 1986). Burning is used by some farmers to prune some species of blueberries on commercial stands, has been found to have a stimulative effect on some species (Vander Kloet, 1988) and to shift the competitive relationship among other species (Reiners, 1965; Buell and Cantlon, 1953). Clay (1981) found that *E. repens* was a persistent member of the undergrowth in a North Carolina area burned every two years.

As a consequence of this information, I decided to evaluate burning as a potential management tool. Burning of areas on more moderate slopes where *E. repens* occurs should reduce litter accumulation to levels found on steeper slopes. It might also reduce competing vegetation.

Three additional studies were done. I analyzed *E. repens* populations in Michigan to determine if the habitat requirements vary substantially outside of south-central Indiana. I compared the sex ratios of flowers from three of the Indiana sites in this study to see if this revealed anything about population isolation or structure. I transplanted stem cuttings to the Griffy Reservoir site to determine if *E. repens* could grow there.

The specific questions looked at in this study are:

1) What are the habitat characteristics of sites containing *E. repens*?

2) What species of trees and other plants are found at these sites?

3) What are the roles of soil pH and competition in the occurrence of *E. repens*?

4) What effect does controlled burning have on *E. repens* in south-central Indiana?

5) Does the sex ratio vary among sites?

6) Can *E. repens* be transplanted and grow in sites where it does not occur but that appear favorable for it?

METHODS

STUDY SITES

Study sites were selected from a list provided by the Division of Nature Preserves and from new sites I discovered. I selected five sites in south-central Indiana for study; four sites with populations of *E. repens* and one seemingly favorable location where it did not occur. Three of these sites were in Monroe County and two were in Morgan County (Figure 3). Sites with *E. repens* included (1) the Frey site (2) the Hongen site and (3) MM-I and MM-II in Morgan-Monroe State Forest just north of the Morgan-Monroe county line. The site without *E. repens* was near Griffy Reservoir.

All of the sites occur in forested areas of considerable relief characterized by steep-sided ravines and ridges. The sites are located in the Brown County Hills Section of the Highland Rim Natural Region (Homoya, 1993).

The soils at the sites have similar characteristics (Soil Survey of Monroe County Indiana, 1981; Soil Survey of Morgan County Indiana, 1981). They are generally friable, well drained, and have a low moisture holding capacity. The top 15 cm of soil typically is strongly acid with a pH from 5.1 to 5.5. The soils developed from sandstone, siltstone and shale on uplands. The top 15 cm of soil may consist of 10% to 30% stone fragments. The bedrock is typically 25 cm to 100 cm from the surface.

Frey Site: The Frey site (39° 8′ N, 86° 29′ W) is located in Perry Township (Figure 4) (Sec. 13, T8N, R1W, Unionville Quadrangle), Monroe County. This site is approximately four km south of Bloomington and is located on the properties of the Frey and Bowie families. The 8 hectare site is along a hillside overlooking Moore Creek. The surrounding 25 hectares of forest at the Frey Site has not been disturbed since 1950 (Frey, pers. comm.). This is a mature forest with red oak, white oak and beech the dominant trees.

Hongen Site: The Hongen Site (Figure 5) (39° 12′ N, 86° 25′ W) is located in Benton Township (Secs. 21 and 16, T9N, R1E, Unionville Quadrangle), Monroe County. This is approximately 13 km east-northeast of Bloomington. The two hectare site is located on the end of a blunt ridge overlooking a stream bed. The 32 hectares surrounding the site have mature stands dominated by oak, tulip tree, beech, maple and hickory. No timber had been cut for an estimated 75-100 years prior to 1984. In the fall of 1984 the landowner, with the advice of a timber management consultant, thinned "undesirable" or dying trees in the forest adjacent to the study plot. The trees were girdled or felled and left on the forest floor. In the summer of 1985 approximately 24 trees per hectare were removed for sale. Two thirds of the trees were removed from the north slopes (Hongen, pers. comm.).

MM-I: The first Morgan-Monroe site is called MM-I

(Figure 6) (39° 21′ N, 86° 27′ W) and is located in Washington Township (Sec. 32, T11N, R1E, Hindustan Quadrangle), Morgan County. This is approximately 33 km north of Bloomington in Morgan-Monroe State Forest. The eight hectare site is located on the sides of a ridge overlooking Gose Creek. The surrounding forests are 60-70% oak-hickory (Breedlove, pers. comm.). Chestnut oak is the dominant tree. The forests surrounding the study site have not been logged for approximately 80 or 90 years (Breedlove, pers. comm.). Most of the land in this area was purchased for the Morgan-Monroe State Forest between 1929 and 1935. The land was intensively logged before the time of purchase.

MM-II: The second Morgan-Monroe site is called MM-II (Figure 6) (39° 21′ N, 86° 26′ W) and is located in Washington Township (Sec. 33, T11N, R1E, Hindustan Quadrangle), Morgan County. This is approximately 34 km north of Bloomington. The two hectare site is located on the side of a ridge overlooking Gose Creek one km west of the MM-I site. The surrounding forests on this site are 60-70% oak hickory (Breedlove, pers. comm.). Chestnut oak is the dominant tree. The forests surrounding the study site have not been logged for approximately 80 to 90 years, although there has been some recent logging (probably in 1989) on adjacent ridges approximately 500 m away (Breedlove, pers. comm.).

The site was damaged by two windstorms in 1990 (May 16 and August 29). The August storm left heavy damage to the west and south of the MM-II site and east of the MM-I site (Breedlove and Calvert, 1992). Salvage of timber occurred during 1991 and 1992 on damaged areas of the forest including areas adjacent to the study sites. In fact, preliminary locations of study plots were changed because of the effect of tree removal and resulting change to the tree canopy.

Griffy Reservoir Site: The Griffy Reservoir site (Figure 7) (39° 12′ N, 86° 31′ W) is located in Bloomington Township (Sec. 22, T9N, R1W, Bloomington Quadrangle), Monroe County. This is near the lake just west of Headley Road. The four hectare site is located on the sides of a ridge bounded by Griffy Reservoir and an intermittent stream. Bedrock in this area includes acidic siltstone and shale covered by a cap of Salem limestone, (Welch, 1929). The forest is mature and dominated by black oak, white oak, red oak and beech, and probably hasn't been logged since the reservoir's construction in 1924.

SAMPLING METHODS TO CHARACTERIZE *E. REPENS* SITES

At the Frey, Hongen, MM-I and MM-II sites a circular plot with a radius of 10 meters was laid out. The plot was centered to encompass an area containing *E. repens* plants. Because of terrain and distribution of *E. repens*, the plots at MM-I and MM-II had to be broken into semi-circular plots adjacent to each other.

Table 2 lists the vegetational and physical features of the habitat measured at each site, along with the codes used to refer to them in the text.

The circular plot was divided into six wedges of 60°. Within each wedge, an angle in degrees was chosen using a random number generator. A meter distance between 0 and 10 was also chosen with a random number generator, thus giving the exact location of the subplot, core or photograph site. For neighboring wedges, distances to each subplot were kept at least 2 meters apart in order to prevent sampling the same area twice. Subplots were randomly located within wedges rather than scattered over the plot as a whole to insure sampling the entire plot (Hurlbert, 1984).

In each of the six wedges a point was chosen randomly. This point was the center of a 2 m radius sub-plot. All woody vegetation > 0.5 m in height and < 2.5 cm dbh was identified and counted within this plot. Although these data were gathered they were not used in the analysis. The center of these sub-plots was also the center of a 1 m^2 sub-plot in which all of the vegetation < 0.5 m in height was identified and counted.

All trees > 2.5 cm dbh in the 10 meter radius plot were identified and the dbh recorded. The basal area of the tree stems was divided by the area of the 10 m radius plot (BASDEN) to give a measure of the biomass or standing crop at the sites. The trees were divided into two size classes to give an indication of age structure, dominance and direction of succession. Species and number of all saplings (SAPDEN) < 2.5 cm dbh and > 1.5 m tall in the 10 meter radius plot were recorded.

I tabulated the number of *E. repens* plants in each of the six wedges and determined the density (plants/m^2 (ERDEN)) by dividing the number of plants by the area of the wedge.

The canopy height (CANHT) of the largest diameter tree in each section was measured with a clinometer. This method is described in Randolph (1991).

The slope (SLOPEDEG) of the study plot was measured with a clinometer by selecting two points on a slope and measuring the angle from the horizontal. One of the two points was directly down the aspect and the other directly above. Both of these points were on the circumference of the circular plot. Slope aspect (ASPECT) was determined with a compass. Methods for measuring slope and aspect were adapted from Hays et al. (1981).

Canopy cover (CC) and litter exposure (LX) were derived from photographs taken at six randomly-located places on the plot. Canopy and litter photographs were not taken at the same places, to avoid artificial correlations in the data. A gridded acetate sheet was placed over a randomly oriented photograph and the gridpoints scored as to whether they fell on canopy or sky (for canopy cover) or vegetation versus litter (for litter cover). Each photograph was counted three times with different random orientations of the photograph.

Percent CC = (number of dots on leaves/ total number of dots) X 100. Percent LX = (number of dots on litter/ total number of dots) X 100.

Litter depth (LITDP) was measured at six randomly-located spots in each plot by poking a thin, calibrated rod into the litter until resistance was felt.

Soil profiles were analyzed at the litter depth points. Loose leaf litter was brushed aside. The rest of the O horizon was left intact and a core sample was taken. The depth of the O (OHORZN), A and B horizons were measured. The soil characteristics of color, texture and structure of the A and B horizons were noted. Color was determined with Munsell soil color charts. These techniques follow Randolph (1991).

Soil pH was measured from soil core samples. Prior to taking soil samples for pH determination I determined the root depth of two *E. repens* plants by excavating the roots around two plants. The majority of the roots occur in the top 2.5 cm of soil while an occasional root extends to 10 or 12.5 cm. Therefore, I decided to analyze the soil pH at two depths: one from samples taken from the top 2.5 cm of soil (PH1) and the other from soil between 2.5 and 12.5 cm deep (PH5). Soil samples used for pH determination were taken on the same day or two consecutive days so sampling conditions such as soil moisture would be similar. The soil samples were frozen until ready for analysis. The analysis included (1) thawing the sample, (2) placing the sample in a 0.01 M $CaCl_2$ solution, and

(3) determining the pH with an Orion model 720A pH meter (Randolph, 1991). Three readings were taken for each sample.

ROLE OF SOIL PH

Preliminary data on soil pH indicated that although both *E. repens* and *Vaccinium pallidum* grow in acidic soils they do not usually co-occur. Consequently, I wanted to know if co-occurrence is influenced by pH. I measured the soil pH of three types of circular plots at MM-I: *E. repens* and *V. pallidum* present (MM-IA), only *V. pallidum* present (MM-IB), and neither *E. repens* nor *V. pallidum* present (MM-IC and MM-ID). These plots were laid out on July 7 and 13, 1993 and had a radius of 10 m. Each of these circular plots was divided into 6 wedges. Soil pH, litter depth, and O horizon depth were measured in random spots in each wedge. The samples were gathered and measured in these four plots using techniques described earlier. The vegetation in a 1 m^2 sub-plot selected at random in each wedge was inventoried.

COMPETITION WITH *VACCINIUM*

The correlations of *E. repens* density versus the habitat data gathered in 1991 and 1992 suggested that competition with *Vaccinium* might be a factor controlling the distribution of *E. repens*. The results of the pH measurements taken in July of 1993 at MM-I also supported this. I wanted to determine whether *V. pallidum* and *E. repens* are competing for sites with similar pH, litter and O horizon depths. To test for this 20 1 m^2 plots at the MM-I site were selected. This work was done during July, 1993. All of these were located in areas that appeared favorable for *E. repens* yet had no individuals. Ten plots contained *Vaccinium pallidum*, and ten did not. I took soil samples for pH determination at 0-2.5 cm and from 2.5-10 cm deep. The litter depth and O horizon were measured and all of the vegetation within the square was identified and counted.

The same procedure was followed at the Griffy Reservoir site for 10 plots with *Vaccinium pallidum* and 10 plots without *Vaccinium pallidum*.

CONTROLLED BURN

Plots containing relatively uniform distribution of *E. repens* on less abrupt slopes were selected at MM-I and MM-II to be burned. Chi-square values indicate that at least 12 plots would be needed to detect for significance at the 0.05 level. Accordingly, sixteen 1 m^2 plots were selected.

The plots were inventoried to record the number of *E. repens* plants, absence or presence of buds and number of leaves. Plot data were gathered using a meter square grid with 100 sections. The side of each section measured 1 dm. Data were collected by assigning a plant to a grid square. Because the plants root from the stem it was not always possible to assign them with certainty to a particular grid.

Great care was taken to assign plants to the burn, buffer and control portion of the plot. Photographs were taken of each plot.

The burn was carried out on March 1, 1992 between 1430 and 1630 hours. The weather conditions were sunny and the temperature was around 18° C.

The fire was generated in a sheet metal frame 16 x 49 x 124 cm. A coin toss was used to decide which side to burn. The frame was placed so that an area of the plot 40 cm x 1 meter was covered. This left a 20 cm wide buffer between the burned and unburned sides. If the litter depth did not equal 12.5 cm leaves from near the plot were placed in the frame to a depth of 12.5 cm. The litter was lighted with a match.

The leaves, stems and buds on the burn, buffer and control portion of the 16 plots were counted after the burn on August 11 and 12, 1992 and on August 16 and 19, 1993. The blossoms were counted on the burn, buffer and control portion of the 16 burn plots on April 17, 1993 and on April 15, 1994.

The results were analyzed using MINITAB Statistical Software.

RECIPROCAL TRANSPLANT EXPERIMENT

There are many seemingly ideal habitats in the study area from which *E. repens* is absent. A transplant experiment was designed to test whether *E. repens* would grow in these potentially suitable areas. After being unsuccessful with rooting cuttings from *E. repens* in the IU Greenhouse, I tried stem layering on 18 plants in the field at the Frey and Hongen sites. Three of these plants formed small roots and were moved to an area at Griffy Reservoir with similar conditions of soil and canopy cover on May 5 1993.

SEX RATIO

Sex ratio may give clues to colony isolation or environmental conditions. To determine the ratio of dioecious plants in different populations I gathered one flower from various *E. repens* clumps at the Frey, Hongen, and MM-II sites. The flowers were sexed and placed in an alcohol solution to preserve them for any future studies or comparisons. Lynda Delph divided the flowers into sexes. Males have short styles with prominent stamens (thrum morph type) and females have a long style with reduced stamens (pin morph type). A chi-square test was done to determine if the ratio was significantly different from a 1:1 sex ratio at the 5% level.

MICHIGAN pH COMPARISON

Some plants grow under different conditions in different parts of their range. Consequently, I measured soil pH and other general habitat conditions in central Michigan, where *E. repens* is frequently found. I collected soil samples from localities in August 1992. Two soil samples were from an area near a campsite in the Sleeping Bear Dunes National Lakeshore in Benzie County and four were from a locality near Pentwater in Oceana County. The samples were approximately 10 cm thick.

The Benzie County site is gently rolling, with an oak-pine forest with *Pteridium aquilinum* (bracken fern), *Gaultheria procumbens* (wintergreen), *Monotropa uniflora* (indian pipes), *Cornus canadensis* (bunchberry), and a *Vaccinium*, *Gaylussacia*, and *Pyrola* species. *Epigaea repens* was found over an extensive area but was not as abundant as at the Pentwater site.

The Oceana County site is a north-facing hillside with a slope of about 20°. *Epigaea repens* was very abundant on the lower side of the hill but was not found at the top or on the south-facing side. The forest was also oak-pine with an understory similar to the Sleeping Bear Dunes site. In addition there was a species of *Gaylussacia* similar to the one found on the Indiana sites.

RESULTS: Indiana sites

SITE CHARACTERISTICS

Physical site characteristics gathered at the four sites with *E. repens* present were correlated for the individual sites and for the combined four sites using SAS. The pooled results are shown in Table 3. The results listed below follow the order of Table 3 beginning with the characteristic with the strongest correlation.

Because of the limited number of data points for the individual characteristics, XY graphs with *E. repens* density as the dependent variable are used to present the data. This is probably the best display of such scattered data points and indicates the general tendencies (Flury, pers. comm.).

Litter exposure (LX)

Litter exposure is percent of ground not covered by vegetation. There is a strong tendency for *E. repens* to be found on sites with greatest litter exposure. The highest density occurs with LX between 30-60% (Figure 8) This is the strongest correlation (0.480 with $\underline{P}$= 0.018) measured at the four sites. It is one of two correlations that is statistically significant at the 0.05 level. The mean LX is 34% and the standard deviation is 15.2%.

Slope (SLOPEDEG)

The highest *E. repens* densities tend to be on the steepest slopes. The slopes in this study ranged from 14° to 31° (Figure 9). Slope is the other correlation that is statistically significant at the 0.05 level (0.458 with P=0.025). In south-central Indiana *E. repens* is found only on slopes and the highest densities are on the steepest sites. The *E. repens* densities in the graph (Figure 9) closely approximate a linear relationship. The mean slope is 21.6° and the standard deviation is 5.3°.

The distribution isn't limited to a single point on the slope but is scattered up and down the hillside, usually starting at the sharpest break of the slope to well below the crest of the ridge. Many times the healthiest appearing plants (largest leaves and longest stems) are found at the steepest parts of the slope.

O horizon (OHORZN)

The highest *E. repens* densities occur where the O horizon is 1.5-2.0 cm deep (Figure 10). O horizon depth is negatively correlated (-0.38) with *E. repens* density. The mean is 2.3 cm and the standard deviation is 1.0 cm.

Aspect (ASPECT)

Epigaea repens is found only on slopes with an aspect between 180° (south) and 330° (northwest). Highest densities are found at 320° (3.3 *E. repens* plants/m^2), 300° (2.2 *E. repens* plants/m^2) and 180° (2.0 *E. repens* plants/m^2) (Figure 11).

Litter depth (LITDP)

The results of the litter depth analysis are inconclusive. Most plants are found between 0 and 3.5 cm LITDP. There are two peak *E. repens* densities, at 0 cm and 2.5 - 3.5 cm of litter depth (Figure 12). The mean is 2.5 cm and the standard deviation is 2.0 cm.

Accurately measuring litter depth is not always straightforward. I tried to choose a random, representative spot to measure but often the surface under the litter is not smooth but contains holes and rotting parts of tree limbs that could affect the results.

Basal area (BASDEN)

Epigaea repens occurs over a wide range of basal areas (5-29 cm^2/m^2). The distribution is somewhat bell-shaped with the peak occurring around 1.7 cm^2/m^2 (Figure 13a). The mean is 1.6 cm^2/m^2 and the standard deviation is 0.7 cm^2/m^2.

An analysis of the size classes (2.5 cm dbh to < 10 cm dbh and $\geq$ 10 cm dbh) of the trees species at the sites revealed that only red maple and beech are represented in both classes.

Canopy Height (CANHT)

This is a measure of the tallest tree in each sub-plot. The range of canopy heights is from 9 m to 56 m. The steepness of the slopes made it difficult to make the clinometer readings. This may be the reason for such large canopy heights. The values should be valid for comparative purposes if not for absolute values. The highest densities of *E. repens* occur where canopy heights are intermediate. (Figure 13b). The mean is 25.4 m and the standard deviation is 10.8 m.

Canopy cover (CC)

Epigaea repens is found in the shadiest areas (cc > 70%) with most of the distribution clustered in areas with 90% canopy cover (Figure 13c). The mean is 82.3% and the standard deviation is 17.8%.

Sapling density (SAPDEN)

There seems to be little pattern of distribution of *E. repens* and sapling density although there is some clustering with lower sapling density, i.e.; from the 0 to 0.12 saplings/m^2. (Figure 13d). The mean is 0.1 saplings/m^2 and the standard deviation is 0.1 saplings/m^2.

Soil pH

Values for the top 2.5 cm of soil (PH1) range from approximately 3.2 to 4.1. The pH of the soil at the depth between 2.5 and 12.5 cm (PH5) ranges from 3.4 to 4.2. Mean for PH1 is 3.5 with a standard deviation of 0.25 and the mean for PH5 is 3.9 with a standard deviation of 0.19 (Figures 14a and 14b) indicating that the top layer of soil is more acidic.

Soil characteristics

Soil samples taken at the sites are Berks soils containing pieces of siltstone. This was confirmed by Paul McCarter (pers. comm.) of the U.S. Soil Conservation Office. Table 4 lists the ranges of the A and B horizons along with the hue and ranges in value and chroma.

VEGETATION

Tables 5 and 6 are a rank-ordered list of species that occur in the four plots that contain *E. repens* in descending order of occurrence. Table 5 is the proportion of herbaceous and woody plants in the sub-plots < 0.5 m high. Table 6 is the count of tree species > 2.5 cm dbh.

An analysis of the diameters of the tree species at each site revealed that trees with a dbh $\geq$ 10 cm are not represented in the class of trees with a dbh < 10 cm with the exception of red maple and beech.

RESULTS OF THE ROLE OF SOIL PH AT MM-I

Table 7 lists the results from the four circular plots set up at the MM-I site in August 1993. The soils are similar at all sites. They are silty loams containing small pieces of siltstone 0.3 cm to 2.3 cm in diameter. The A horizons are thin. The B horizons are 7.5 to 37.0 cm deep. I encountered a stony layer under the B horizon that prevented the coring tool from penetrating farther without using great force.

RESULTS OF THE MM-I AND GRIFFY COMPETITION STUDY

Studies were conducted in August 1993 to determine the role of competition in the occurrence of *E. repens*. The highest *Vaccinium* densities were found in soils with the thickest O horizon (Fig. 15a) and in what appeared to be the sunniest areas. The highest *Vaccinium* densities are also found where the pH is between 3.2 and 3.4 (Fig. 16a) at Griffy and MM-I. *Gaylussacia baccata* appears to have the highest densities in the sunniest spots.

CONTROLLED BURN

A count of blossoms in April, 1993 (13.5 months after the burn) revealed that burning has a decidedly negative effect. A one-way ANOVA showed that the mean number of flowers on the burn, buffer and control groups differ (Table 8) indicating that the burn had a significant negative effect on the ability of the plants to flower in the following year. Given that the variances were shown to be unequal, a Kruskal-Wallis' non-parametric one-way analysis of variance was also performed. The results were the same.

The count of the blossoms in April, 1994 (25.5 months after the burn) revealed that the burn portions of the plots still flowered less than the control or the buffer portions. However, a one-way ANOVA showed that the difference was not statistically significant (Table 9). A Kruskal-Wallis' non-parametric one-way analysis of variance gave the same results.

In August 1993, approximately 17.5 months after the burn, a second post-burn census was conducted of stems, leaves and buds on the burn plots. There are fewer leaves, buds and stems on the burn plots than on the control plots or on the buffer but the difference is not statistically significant. Table 10 gives the mean increase or decrease for the treatments.

RECIPROCAL TRANSPLANT EXPERIMENT

The 3 plants that were transplanted to the Griffy site on

May 5, 1993 from the Frey and Hongen sites were dead as of July 19, 1993.

FLOWER SEX RATIO

Table 11 summarizes the ratios that were found. At all sites the ratio is somewhat female biased, but chi-square tests indicated that the ratios were not significantly different from a 1:1 sex ratio at the 5% level.

RESULTS: Michigan sites

MICHIGAN pH MEASUREMENTS

The soil pH at the two Michigan sites was almost identical. It ranged from a high of 3.3 at the Sleeping Bear Dune National Shoreline to a low of 3.2 at the Pentwater site. The standard deviation was 0.09.

DISCUSSION

This study concentrated on describing the habitat parameters of four sites where *E. repens* is present and the effect of burning on *E. repens*. I also studied the role of soil pH and competition, why *E. repens* does not occur in what appear to be suitable habitats and the sex-ratio of plants at 3 sites.

Litter exposure (LX)

Litter exposure is not strongly correlated with the other variables indicating that this is an important factor. The convex positions on the slopes of the *E. repens* sites and the south and southwest aspect of some of the sites may lead to reduced moisture because of insolation (Spurr and Barnes, 1980) and therefore less ground level vegetation. The insolation received, especially in winter when there are no leaves on the trees, dryness caused in part by the steepness of the slopes and the poor soils would be harsh environments for many plants and lead to lower LX values.

From the photographs, leaves of *Viburnum*, *Carex picta*, *Vaccinium pallidum*, *Smilax*, and *Fagus* saplings appear to be the main vegetation on the forest floor with *Carex* accounting for most of the ground cover. *Epigaea repens* does not occur where there is a lot of other vegetative competition.

Slope (SLOPEDEG)

Although slope appears to be an important determinant of occurrence of *E. repens* in Indiana, it doesn't appear to be a decisive factor elsewhere in its range. *Epigaea* is found on both slopes and flat areas elsewhere (Barrows, 1936; Barrows, 1947; Clay, 1983). I observed two such sites in Michigan with well-drained, sandy soil. One was at Platte River Campground (a relatively flat area) in the Sleeping Bear Dunes National

Park and another on a hillside east of Pentwater, Michigan.

O horizon

The roots of *E. repens* are primarily shallow and in the O horizon depth. This may be because of the need to propagate vegetatively. It could also be because other plants capable of stronger root competition such as *G. baccata* and *V. pallidum* may have their roots at greater depth (Reiners, 1965). Depth of O horizon seems to be very important for the growth and distribution of *E. repens* possibly because of soil moisture, mycorrhizal association, and nutrition. It would appear that O horizon depths between 1.5 and 3 cm provide the best environment for the shallow roots of *E. repens*. Councilman (1923) reports that on Cape Cod it occurs in a variety of soils from stiff clay to sand with the common feature being the thin layer of overlying humus. He reports that the greatest number of roots are found in or just below the surface "ramifying" in the humus.

Aspect (ASPECT)

Aspect of the slope would affect factors such as light, temperature and soil moisture. The aspects of the slopes are clustered between due south and NW (figure 11). *E. repens* seems to prefer dry conditions.

In the North Temperate Zone the south-facing slope receives more intense sunlight. This would be the warmest and driest slope followed by SSW, SW and SSE-facing slopes. NW-facing slopes would be somewhat cooler since they would not receive such intense insolation (Spurr and Barnes, 1980).

The Frey and MM-II sites have the most northern aspects and the steepest slopes. If *E. repens* prefers dry conditions then a steep slope would offset the moister conditions expected on a NW-facing slope.

I am not sure why there are no east-facing slopes. A survey of the aspect of additional *E. repens* sites would reveal if this relationship holds or is due to the limited number of sites that I examined.

Litter depth (LITDP)

Litter is an important source of nutrients and acts to hold moisture. The decomposition rate is usually in equilibrium with the yearly addition of litter. Warmth, moisture and aeration favor decomposition while factors such as acid conditions inhibit decomposition (Spurr and Barnes, 1980). Leaf litter accounts for approximately 70% of the total litter depth (Bray and Gorham, 1964). That is what I primarily measured.

Litter depth may affect the stem rooting of *E. repens*. Too many leaves could bury the plant but a certain thickness may be needed for the formation of adventitious roots by providing moisture around the stem. In fall and winter the litter depth would be greatest providing the mature stems with moisture that would encourage rooting. The fallen tree leaves would decay, releasing nutrients. Litter would decrease in depth in the spring and summer as the flowers blossomed and the new growth emerged. Fallen leaves and other litter may also provide protection from sun and cold in the winter.

The litter depth measured suggests that the decomposition rate and litter accumulation are in equilibrium. My impression is that in other areas of the forest in south-central Indiana with richer, moister and more pH neutral soils there is less leaf litter.

Basal area (BASDEN)

Basal area was measured to give an estimate of the woody biomass of the sites and thus a measure of site quality, dominance and direction of succession. It is very difficult to isolate the effect of a large canopy tree to a small area on the ground. A tree on the outer edge of a sub-plot could shade, absorb moisture and nutrients or drop leaves on the entire 10 m radius plot. Different ages of the tree stands and frequency of blow-downs in each would affect comparisons between sites.

The highest *E. repens* densities are found at intermediate BASDEN values, suggesting that some disturbance in the forest is advantageous to its growth.

The analysis of the two size classes (2.5 cm dbh to < 10 cm dbh and $\geq$ 10 cm dbh) indicated that only red maple and beech are represented in both. Red maple and beech may replace oaks as the dominate trees in the future forests at these sites.

Canopy height (CANHT)

Canopy height was measured to give an indication of site quality or forest productivity and as an indicator of forest age. Tree height is independent of stand density over a wide range of densities and so it is a good indicator (Spurr and Barnes, 1980). The effect of a canopy tree in one sub-plot is probably not limited to that sub-plot. The different ages of the tree stands and frequency of blow-downs in each would affect comparisons between sites.

As found with BASDEN, the highest *E. repens* densities are found at intermediate CANHT values. This suggests that some disturbance in the forest is advantageous to its growth. The wide range of CANHT values (as well as BASDEN values) indicates that *E. repens* is somewhat variable in its habitat requirements.

Canopy cover (CC)

Canopy cover was measured to discover the light conditions favored by *E. repens*. With greater canopy cover there would be less light reaching the forest floor and therefore a less developed surface and shrub layer.

Reports in the literature suggest that *E. repens* may occur under varying light conditions. Councilman (1923) states that in New England it does not flourish in deep shade but prefers the forest edge or the side of a forest road. Arland (1945) found the leaves of plants from dense shade well developed but with few flowers while those from sunnier locations are scant but the plants have more blossoms. Barrows (1947) observed that in the East the most numerous flowers were produced in partial shade.

I did not measure flower production in relation to canopy cover but did observe that many of the plants at the sites produced many flowers during the spring of 1992 and 1993. The mean number of flowers on the control portion of the burn plots (28.5 $\pm$7.63) indicated that substantial flowering was occurring.

The sites in south-central Indiana are characterized mainly by high canopy cover percentage. In reality, the CC values would be even higher if we consider that the single plot at MM-I with the lowest CC % had a large (55.5 cm dbh) red oak fall in 1990 prior to measurement. If an allowance is made for the shade that this tree would have created then the lowest canopy values would be shifted to reflect even higher CC values (Figure 13c).

The slope and aspect will affect light intensity. Because of the aspect and the steepness of the slope the light intensity may be higher than indicated by CC. Since *E. repens* is an evergreen species it may be able to grow significantly before the canopy closes in completely. *Epigaea repens* is not found in interior parts of the forest. Although I did not measure light intensity it is my impression that *E. repens* is found on the ends or sides of ridges which receive more insolation than interior parts of the forest.

The canopy cover values (mean of 82.3%) indicate that canopy closure is not complete. This would agree with the observations that *E. repens* is not found in complete shade. Frazer (1992) found CC values of 95-99% in mature forests (unless limb or tree falls occurred) in south-central Indiana. Values for *E. repens* sites point to mature forests that have some disturbance or lower productivity because of poor site conditions. High canopy cover values would inhibit the development of a dense shrub layer or surface vegetation.

Sapling density (SAPDEN)

The sapling density will give an indication of forest age structure (succession), site quality and canopy closure. A large number of saplings can indicate forest disturbance or stress (Oldeman, 1990). These conditions are found after tree falls or soon after clearcuts (Frazer, 1992).

The very low sapling densities found at the *E. repens* sites suggests that the forest site is not experiencing great disturbance and is possibly another indication of poor site conditions (low water and nutrient availability) for plant growth. Low sapling density may be related to high canopy cover values (see figure 13c and 13d).

pH (pH1 and pH5)

Although pH is listed last in the correlation table (table 3), it is definitely very important in the broad scale distribution of *E. repens*. A low soil pH is necessary for *E. repens* but it is tolerant of varying pH levels. Wherry (1920a and 1920b) described the pH values he found for *E. repens* populations in Vermont, Pennsylvania and Maryland. He reports that *E. repens* is found on soils with a reaction of 30 or mediacid; i.e., pH 5 to 6 (Clark, 1928) to just below 10 or minimum; i.e., pH 6. Although it is hard to correlate his terminology to a numerical pH level, his levels do indicate that *E. repens* is found at a range of pH levels that are more basic than at Indiana and Michigan sites.

In south-central Indiana *E. repens* occurs in localized patches. In these patches the soil pH is low. It occurs within a narrow pH range but its density isn't correlated with a particular pH value. Below (and presumedly above) a certain level it can grow if other conditions are favorable.

Soil characteristics

The soils at all of the *E. repens* sites are very uniform. The characteristics that most affect the plant communities that occur on these soils are their well-drained nature, low or very low capacity to hold moisture, low pH values and shallow depth to bedrock. Seedling mortality is high and depth to bedrock limits tree growth (Soil Survey of Monroe County Indiana, 1981).

Vegetation

The vegetation of trailing arbutus sites is easy to characterize. Typical trees of the forest are Chestnut oak or other oaks. The shrub layer contains *Smilax rotundifolia*, *Gaylussacia baccata* and Vaccinium pallidum. The herb layer contains *Carex picta*. Of the two plants listed in table 3 occurring in the most sub-plots, *V. pallidum* is the most important as an indicator of *E. repens* occurrence because it is restricted to soils with similar pH levels. *Carex picta* is local and confined to about seven counties in south-central Indiana (Deam, 1984) but is found more widely than *E. repens*. It is also confined to dry upland forests dominated by chestnut oak (Homoya, 1993). *Acer rubrum* is listed third but is not a good indicator species because it is a very cosmopolitan species (Harlow, 1968). Although *G. baccata* was noted near and within the plots I did not record any in the 1 m^2 sub-plots. At other sites *E. repens* and *G. baccata* are found growing together.

Soil pH and distribution of *E. repens* and *V. pallidum*

At first glance the results of the pH measurement at MM-I in 1993 (Table 6) suggest that *E. repens* and *V. pallidum* are excluded from two of the plots because of higher soil pH values. But earlier measurements show that *E. repens* is found in sites with a soil pH as high as 4.2. Shade or other factors are probably operating here. Wherry (1920a) found that *E. repens* and *V. pallidum* both prefer a soil pH of 30 or subacid; i.e., pH 5 to 6 in standard terms (Clark, 1928). The peak values for *V. pallidum* are 30-10 with a range from 1-300 (i.e. neutral to pH 4-5). The peak values for *E. repens* are 30, 300 followed by 100 with a range from 10-300 (i.e. pH 6 to pH 4-5). My data also suggest that both species are found over a relatively wide range of soil pH levels that overlap.

Competition with Vaccinium

Data on pH preferences of *V. pallidum* and *E. repens* (Fig. 16A and B) strongly suggest that both species occur in soils where the pH is similar. The highest densities for both occur between pH 3.2 and 3.6. *Vaccinium pallidum* occurs in 20 out of the 24 sub-plots inventoried in 1991 (Table 3); it was absent only from 4 sub-plots at the Hongen Site. This co-occurrence suggests that they must compete at and for the same sites. However, as indicated earlier, factors other than soil pH influence the occurrence of *V. pallidum* since the soil pH is the same in plots where *V. pallidum* is absent and present (Figure 16A).

An analysis of the effect of O horizon depth on plant density (Figure 15 A and B) gives clues to one of these factors. For example, *Vaccinium pallidum* densities increase with increasing O horizon depth while *E. repens* densities are greatest between 1.5 and 3.0 cm and decrease at greater depth.

The common features of all *E. repens* sites in south-central Indiana seems to be a soil pH between 3.2 and 4.2, well drained soils on rather steep, shady slopes oriented between due south and northwest. The O horizon depth is between 1.5 and 3.0 cm and there is a lack of competing understory vegetation. Intermediate basal area and canopy height suggest that *E. repens* occurs in semi-mature forests with some disturbance. Low sapling densities are probably related to high canopy cover, forest age and soils. The canopy is dominated by oaks and the ground layer often includes *C. picta* and *V. pallidum*. The canopy cover allows enough light for *E. repens* but is not favorable for a dense shrub layer or surface vegetation. Unfortunately, a weakness of the study is apparent here since there is little comparative data to characterize mature, disturbed, or intermediate forest.

<u>The effect of prescribed burn</u>

Evidence at this point indicates that burning is not a useful management tool for *E. repens*. Instead, the data suggest that burning has a negative impact on *E. repens*. This is suggested by the low count of leaves, stems and buds on the burned portions of the plots, although the results are not statistically significant. In addition, my impression is that leaves from the burned areas were smaller. Additional counts in another year or two are needed to see if the results remain the same or if there are delayed positive benefits from burning.

Alternative burning dates might lead to different responses. If *E. repens* were burned during the summer after its major photosynthetic activity of the year it might respond better.

Flowering is most affected by burning. Flowering was much less 13.5 months after the burn and mean bud number decreased on the burn plot. Seventeen and 1/2 months after the burn, mean bud number was lower (a 8.3% decrease) on the burn portions. During the same time, the mean bud number increased 148% on the buffer and 27.4% on the control portions. Although, the mean blossom number on the burn portions had increased from the previous count it was still lower than on the control portions.

The easiest measure of the effect of the burning seems to be a count of the flowers. They are easy to census and there is no ambiguity because a flower is either present or it is not. Several problems arise when counting leaves. Small leaves and large leaves are counted as equal. Leaves and stems are also difficult to count accurately. Because trailing arbutus stems root so readily it is not always apparent when one stem stops and a new one begins. The very act of censusing affects the plants. They must be touched and manipulated to be counted. Delicate roots of newly established stems are easily disturbed no matter how careful the counter is. The leaf litter is removed for the counting and although it was replaced after the count it introduces a bias that may favor the buffer and control portions of the plot.

In Ontario, *E. repens* was one of a few species with a shallow rhizome system that is nearly eliminated by fires with a hundred percent surface coverage and with a sufficient intensity to burn into the soil (Stocks & Alexander, 1980). My burn did not have such a dramatic effect because the fire was much less intense. The burn removed the leaf litter but did not affect the O horizon significantly. I did not measure fire temperatures because of lack of time. Strait (1986) used pyrometers at ground level and at various soil depths of a controlled burn of a prairie and give an indication of burn temperatures. She found that the maximum above ground temperature was 400° celsius and less that 100° celsius 2.5 cm below ground level. The *E. repens* fires were probably cooler especially below ground level because there was less combustible material for fuel.

Transplant experiment

The transplant experiments are inconclusive. It is impossible to tell if the transplants failed to grow because the stem cuttings were not ready to be moved or if the failure was due to soil differences at the Griffy Site. Growing *E. repens* from seed has the potential of producing large numbers of plants for transplant (Barrows, 1936; Arland, 1945; Barrows, 1947). A transplant experiment has great potential to show whether present distribution is historical or due to other factors.

Sex ratio

The site with the highest *E. repens* densities (MM-I) has the highest percentage of female plants. This seems to be consistent with other findings that sex ratios in dioecious plants appear to be an indication of resource availability (Hutchings, 1986). The abundance of female plants means that seed producing plants are available. Little can be said about colony isolation from the limited number of data points. Clay (1981) found a pistillate or female bias in 10 out of 14 populations in a study in North Carolina.

Michigan sites comparison

The Michigan comparison pointed out that steep slopes aren't always necessary for *E. repens* to thrive since one of the areas was almost flat. The vegetation found in these oak-pine areas (*Gaultheria procumbens*, *Pyrola*, *Monotropa uniflora* (indian pipes), *Cornus canadensis*, and a *Vaccinium* and *Gaylussacia* species) are plants that are restricted to acidic soil. The soil pH matched the lower levels found at the Indiana sites.

CONCLUSIONS

The *E. repens* habitats that I studied have definite characteristics. The litter exposure is high. The slopes range from 13° to 32° with an aspect between 180° and 300°. The soils are well drained, acidic (pH 3.2 - pH 4.2) with an O horizon up to 4.5 cm thick. The canopy cover is high and the sapling density is low.

Evidence that *E. repens* is a poor competitor is based on the fact that the greatest densities occur where litter exposure is highest. There is a strong tendency for the steepest slopes to support the highest densities of *E. repens*. Competition with *V. pallidum* may help account for the distribution of *E. repens* because it is excluded from potentially favorable sites.

Epigaea repens occurs in a community of other "acid loving" plants that include *Gaylussacia baccata*, *Vaccinium pallidum*, *Carex picta*, *Mitchella repens*, and *Isotria verticillata*. These plants exist in an environment that would be harsh for other plants because of shade and/or low pH (Grime, 1979).

The heath-shrub synusia described by Reiners (1965) is a good model to use in looking at *E. repens* and related plants found with it in south-central Indiana. This "blueberry community" is not common in Indiana and occurs in xeric habitats with acidic soils. *Gaylussacia* is restricted to the sunniest sites while *V. pallidum* can occur in deep shade and full sun. *Epigaea repens* occupies an intermediate position between deep shade and high light intensities where competition is reduced.

Reiners (1965) looked at the root distribution of *G. baccata* and *V. pallidum*. He found the rhizomes of *G. baccata* to be distributed entirely near the surface (concentrated in the a_1 horizon) with no taproots. *Vaccinium pallidum* rhizomes are also found in the A_0-A_1 horizon and occasionally are found in the A_2 horizon. Tap roots are present and descend to at least 70 cm. I found that the roots of *E. repens* are mostly found in the top 2.5 cm of soil (A_0 - A_1 horizons) with an occasional root descending to around 10.0 cm. *Gaylussacia baccata*, *V. pallidum* and *E. repens* are all rhizomatous and clonal (Reiners, 1965; Vander Kloet, 1988) and readily propagate vegetatively. *Epigaea repens* occupies soils where the O horizon depth is thinner than those preferred by *V. pallidum*.

The ultimate question is whether the habitat limits distribution or whether historical factors have limited or eliminated *E. repens* in much of Indiana. These historical factors could include climate change, clearing and logging of forests since settlement by Europeans, and lack of seed dispersal to the scattered low-acid sites.

Possibly *E. repens* doesn't occur at the Griffy Reservoir site because of lack of dispersal or subtle edaphic conditions. This area is the very western edge of Berks soil and possibly the soil is not suitable for its growth.

Many sites similar to those supporting *E. repens* are found in scattered locations in the unglaciated portion of the state (e.g., Brown County). These habitats support *Carex picta* and *Vaccinium* spp. but no *E. repens*. Homoya (1993) and Huffman (pers. comm.) have similar questions relating to the lack of distribution of *I. verticillata* and *C. picta* in what appear to be suitable habitat. The limestone origin of soils in Monroe County might supply an important ingredient (Hill, pers. comm.) not present in Brown County.

MANAGEMENT RECOMMENDATIONS

Epigaea repens should continue to persist in south-central Indiana as long as the populations in Morgan Monroe State Forest and on private land remain protected. The biggest threat is habitat destruction. In the 19th century and in the early 20th century it seemed that *E. repens* had to picked to be enjoyed. A 1936 letter in the Deam Herbarium from Mrs. Fred Elbel about a population near Mishawaka illustrates this point. "We were very careful not to destroy the patch by gathering too much of it. However, other nature lovers found the same spot as the years went on and now the place is much depleted." I hope people will now enjoy it where it grows.

I recommend that controlled burning not be used as a management tool at sites containing *E. repens* unless a future census reveals a strong positive response. The Forest Service has been using controlled burns to increase the number of oaks and to eliminate species such as *Acer rubrum* from experimental plots. Areas containing *E. repens* should not be burned.

Fire effects on *G. baccata* and *V. pallidum* are different. *Vaccinium pallidum* cover rose after burning while *G. baccata* dropped (Buell & Cantlon, 1953). Burning may increase the competitive edge of *V. pallidum* over *E. repens*. *Gaylussacia baccata* is probably not a factor since it is usually found in sites with higher light intensities than favored by *E. repens*.

In the Morgan/Monroe State Forest all areas containing *E. repens* should be identified and protected. After the 1990 wind storm severely damaged extensive areas of the forest salvage operations continued for two years from 1991 until 1992. Salvaging of trees should not have occurred as close as it did to the MM-II site. Removal of damaged trees decreases the shade needed by *E. repens* and allows the shrub layer to dominate. Logging roads and log skidding may destroy patches of *E. repens*.

In the future I would like to identify and map other *E.*

repens sites to see if there is a pattern to its distribution in this area. In addition I would like to again try planting seed-grown plants in the Griffy site area to see if they will thrive there. I would recommend a low intensity burn of about one hectare of an *E. repens* site at Morgan-Monroe State Forest if future flower inventories of the 15 burn plots indicates that the burned plants flower substantially more or exhibit more vigorous growth than the unburned plants.

The four sites in this study were marked with stakes of pvc pipe at the center and along the circumference at each plot section. The burn plots are similarly marked. It is possible to return in the future to monitor the increase or decrease of the *E. repens* populations.

LIST OF TABLES AND FIGURES

Table 6. Proportion of sub-plots containing species from the count of trees > 2.5 cm dbh

Table 7. Average soil pH levels at MM-I site (1993)

Figure 15. *Vaccinium pallidum* (plants/m^2) versus O horizon (top) and *E. repens* density (plants/m^2) vs. O horizon (bottom).

Figure 16. *Vaccinium pallidum* (plants/m^2) versus pH of top 2.5 cm of soil (top) and *E. repens* density (plants/m^2) vs. pH of top 2.5 cm of soil (bottom).

Table 8. Mean *Epigaea repens* flowering 13.5 months after controlled burn

Table 9. Mean *Epigaea repens* flowering 25.5 months after controlled burn

Table 10. Mean differences in the number of leaves, stems, and buds before the controlled burn and 17.5 months after the burn

Table 11. Sex ratios of *E. repens*.

Figure 1. Distribution of *E. repens* in North America. Distribution information from state and provincial herbariums and state and regional floras. See Appendix I for sources.

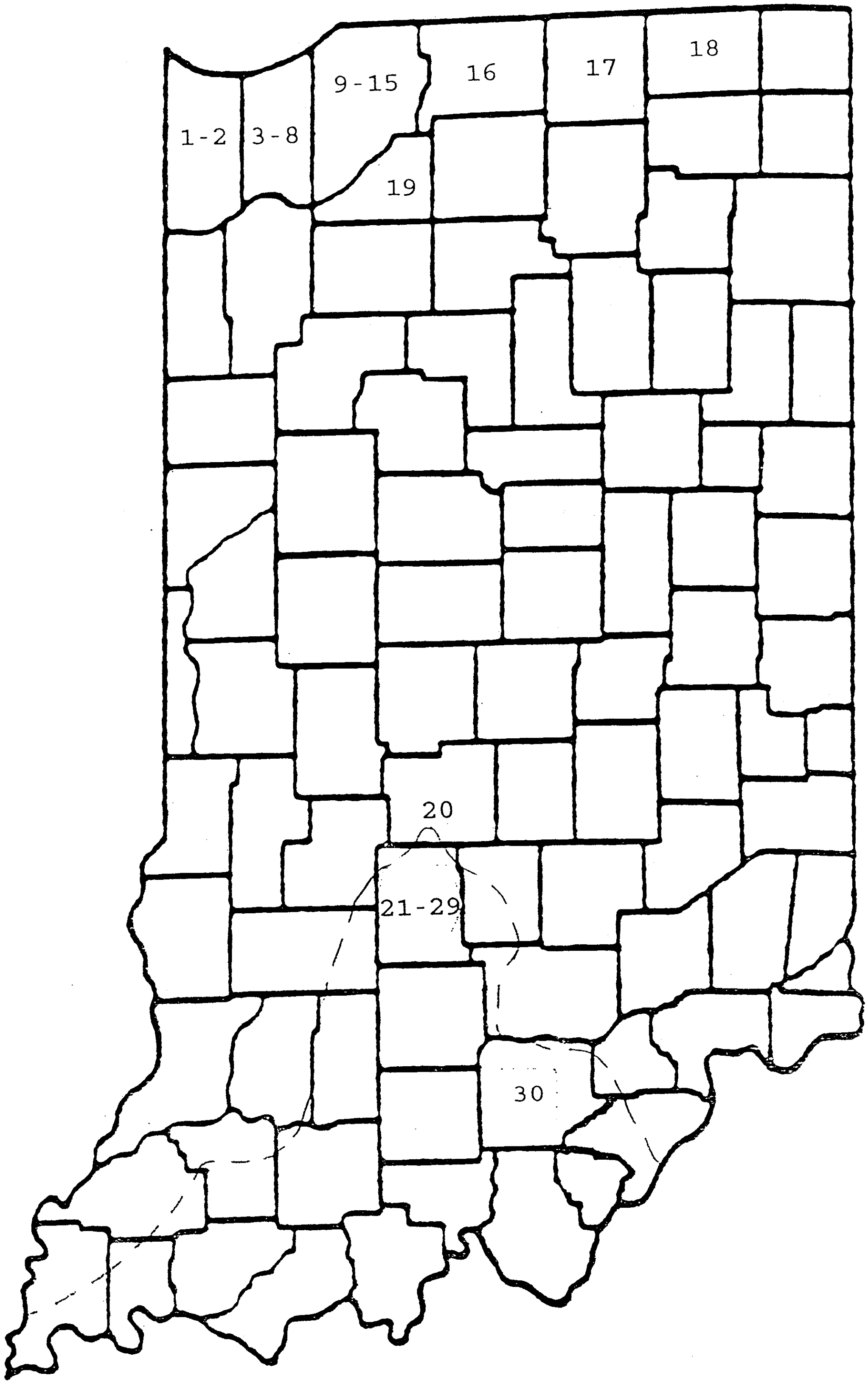


Figure 2. Map showing locations of *E. repens* in Indiana (1905-1993). Refer to Table 1 for more location information. Dashed line shows southern extent of Wisconsin glacier.

Table 1.

EPIGAEA REPENS LOCATIONS IN INDIANA
From Division of Nature Preserves
and other sources

	County		Location	Date 1st located
1.	Lake		Deep River, Liverpool	04-22-03
2.	Lake		S. of Deep River	07-25-85
3.	Porter		E. of Tremont	1910
4.	Porter		Dunes State Park	05-02-85
5.	Porter		Dunes Acres East	1988
6.	Porter		Dunes Acres West	1988
7.	Porter		Chesterton	05-01-43
8.	Porter		Beverly Shores	05-04-47
9.	La Porte		Trail Creek, Springville	05-28-85
10.	La Porte		Michigan City	04-26-30
11.	La Porte		near Michigan-Indiana line	04-20-40
12.	La Porte		Barker Nature Preserve	1983
13.	La Porte		Poplawski Tract	11-12-87
14.	La Porte		Northeast of Michigan City	05-16-87
15.	La Porte		half-mile SW of State Prison	1988
16.	St. Joseph		4 miles SE of Mishawaka	01-31-36
17.	Elkhart		2 miles SE of Vistula	07-08-38
18.	La Grange		3 miles E of Ontario	05-18-15
19.	Starke		PNA 16 (Sec. 28 T33N,R1W)	08-15-85
20.	Morgan	*	Morgan-Monroe St. Forest	04-18-87
21.	Monroe		Arbutus Hill-4 mi. E of Bmgtn.	06-10-21
22.	Monroe		Kerr Creek Road-E. of Bmgtn.	1981
23.	Monroe	**	Libby Frey	1981
24.	Monroe	***	Rob Hongen-Mt. Gilead/Birdie Galyan Road	1991 (new)
25.	Monroe		Lauer/Kuzma-Swartz Ridge Rd	1993 (new)
26.	Monroe		Bender Hollow	1984
27.	Monroe		Filtration Plant by Shields Rd.	1984
28.	Monroe		North of Paynetown Recreation Area	1984
29.	Monroe		Deam Wilderness	02-01-88
30.	Washington		9 mi. E of Salem	04-23-23

* Morgan-Monroe I and Morgan-Monroe II sites
** Frey site
*** Hongen site

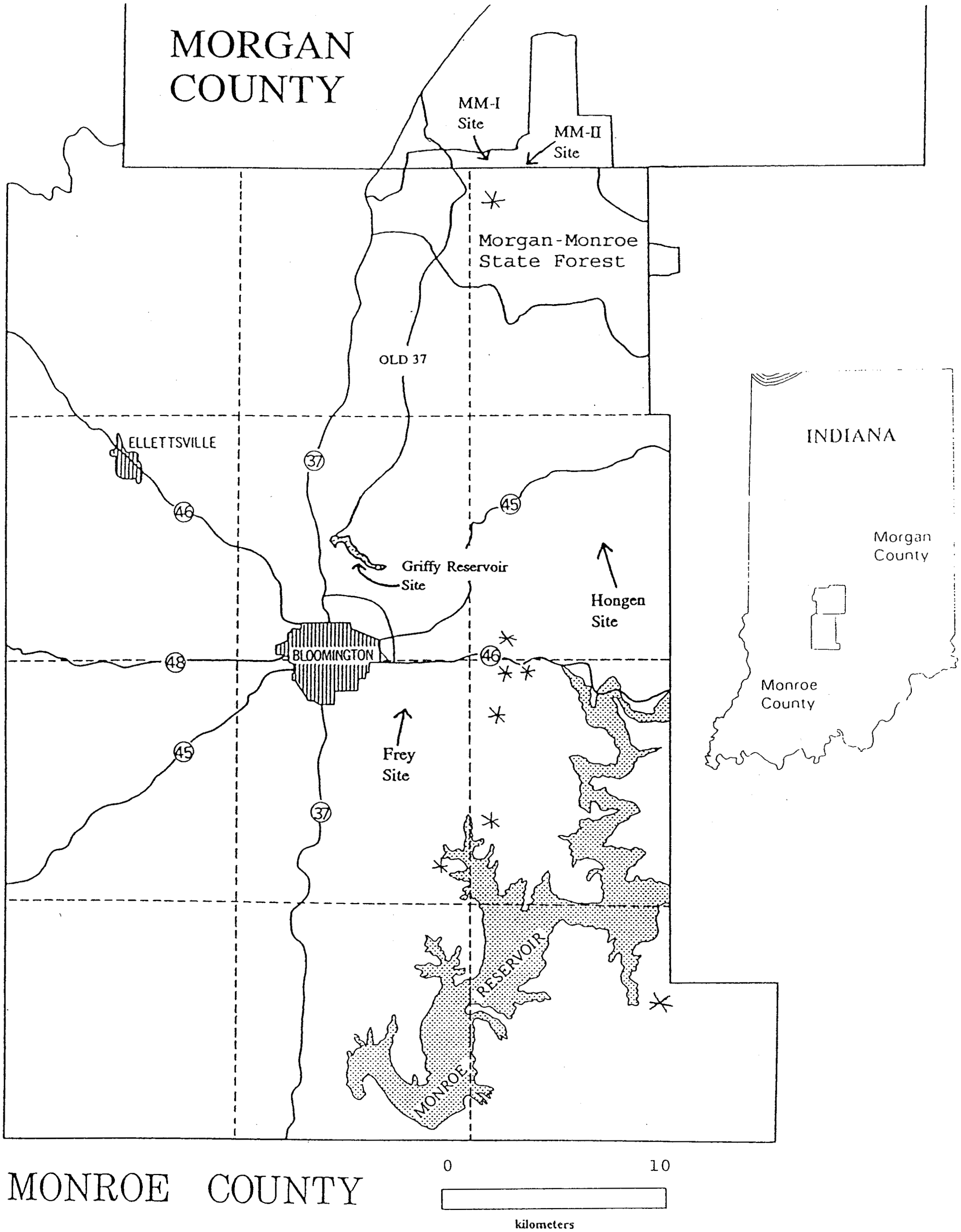


Figure 3. Location of Study Areas in Monroe and Morgan Counties. The 5 study sites are indicated with arrows. An asterisk indicates known *E. repens* sites that were not studied.

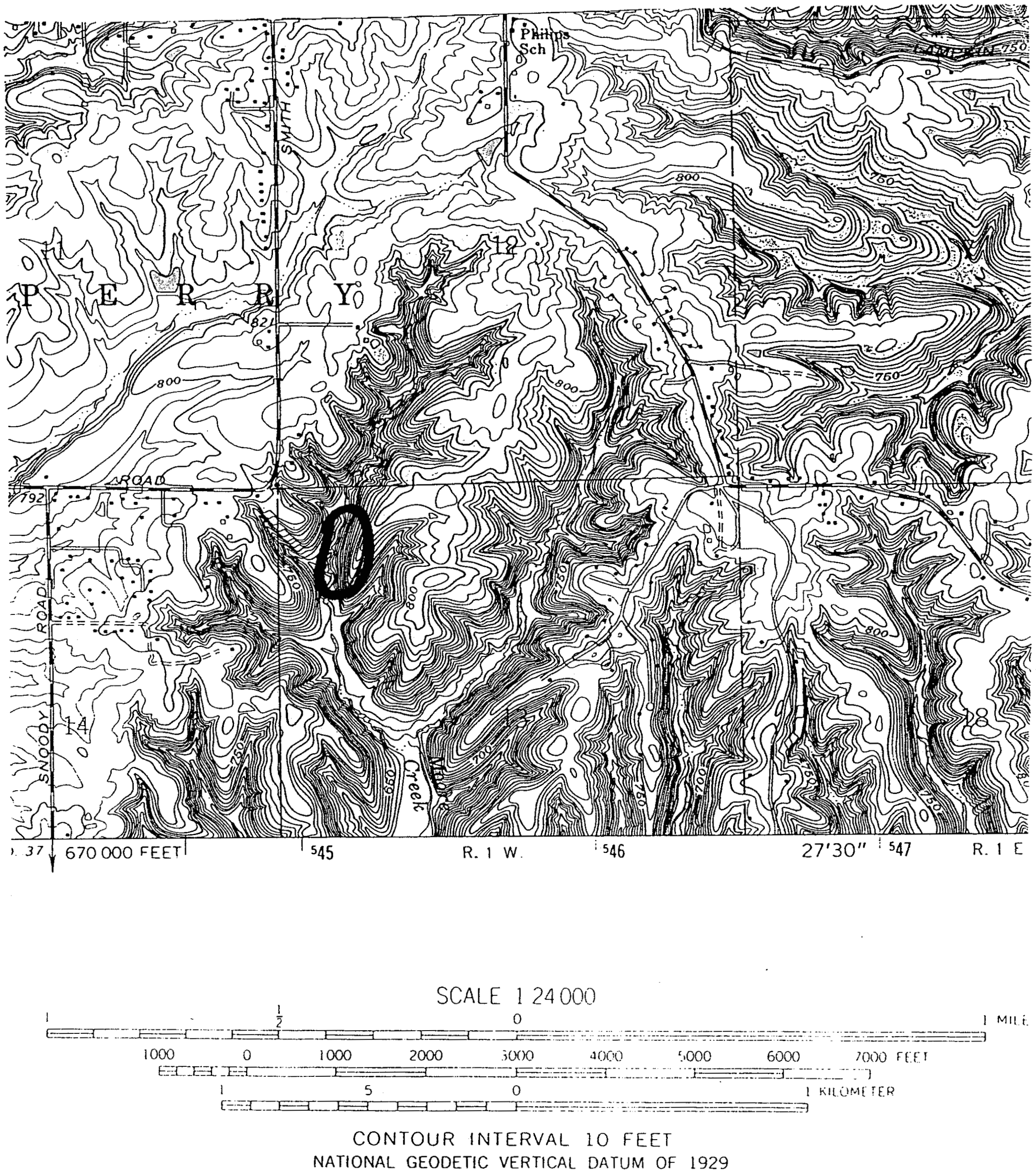


Figure 4. Frey Site

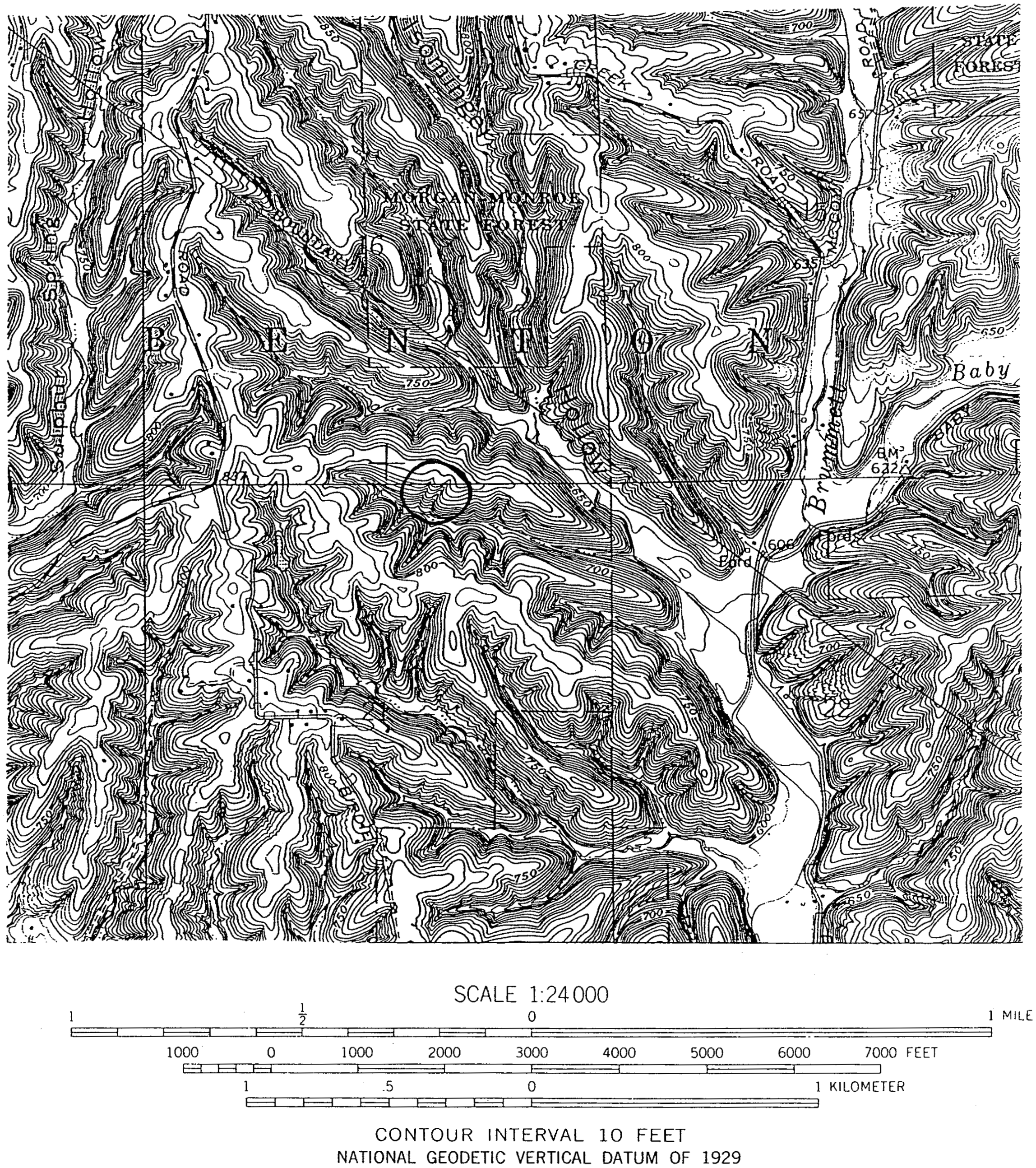


Figure 5. Hongen Site

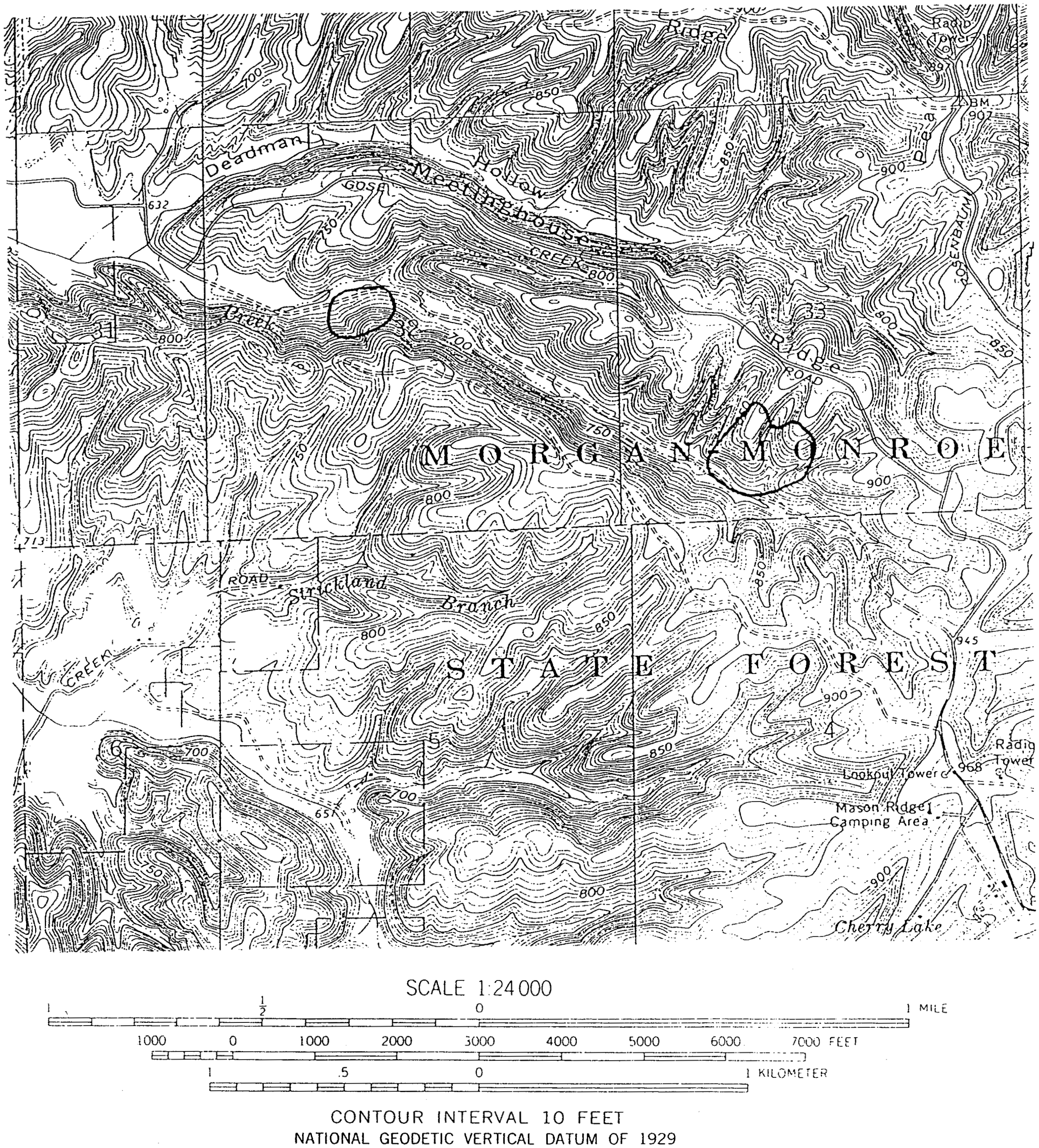


Figure 6. MM-I Site (at right) and MM-II Site (at left)

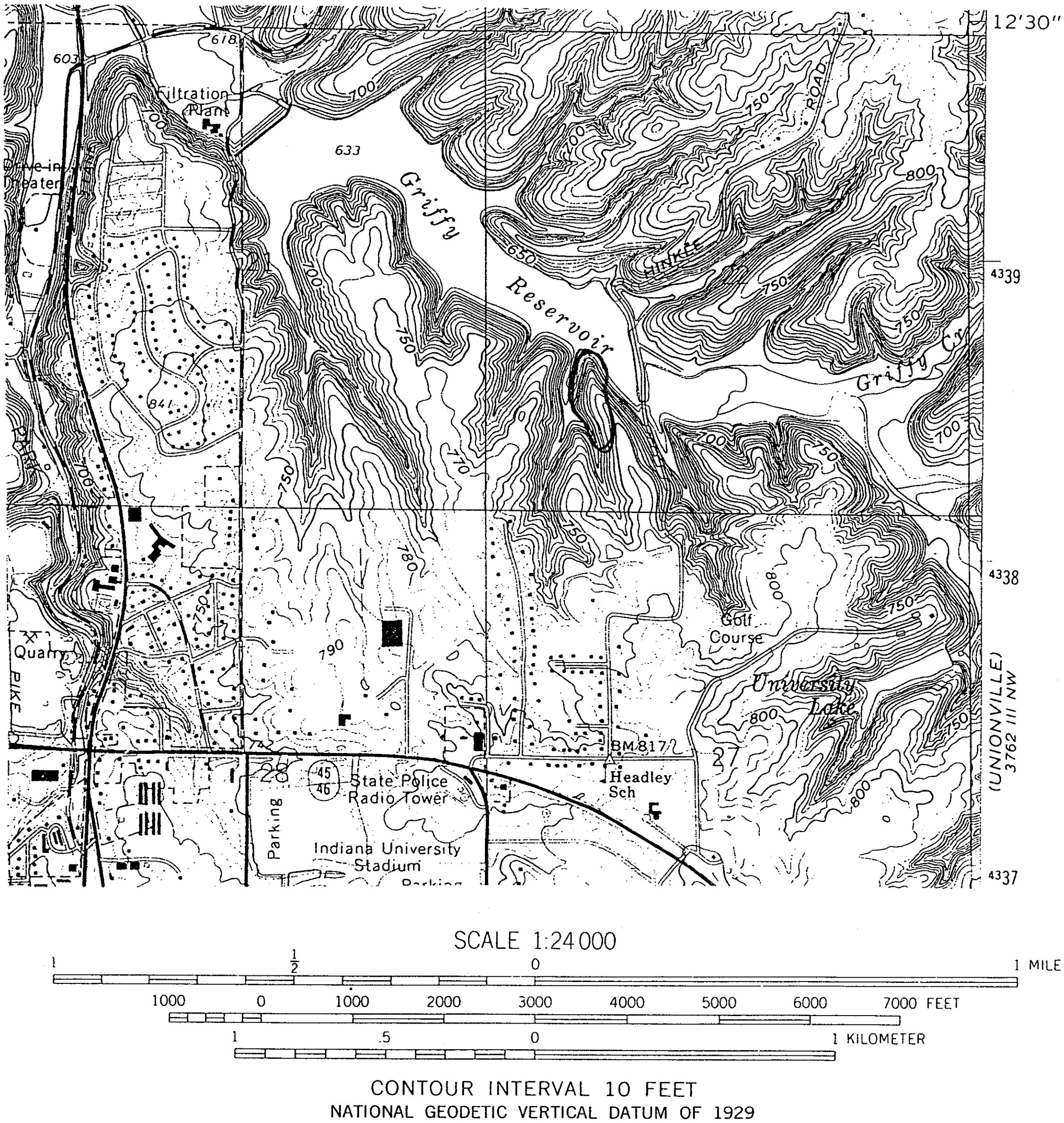


Figure 7. Griffy Reservoir Site

Table 2. <u>Habitat Variables and Codes</u>

Vegetation inventories:

(1) species and diameter of all trees > 2.5 cm diameter -- over entire plot

(2) vegetation > 0.5 m tall and < 1.5 m tall -- -- in 2 m radius sub-plots

(3) vegetation < 0.5 m tall -- in 1 m^2 sub-plots

Area of trees stems at dbh > 2.5 cm	BASDEN
Density of trees < 2.5 cm dbh and > 1.5 m tall	SAPDEN
Density of Epigaea repens	ERDEN
Height of tree canopy	CANHT
Slope of plot	SLOPEDEG
Aspect of plot	ASPECT
Percent canopy cover	CC
Percent litter exposure	LX
Depth of litter	LITDP
Depth of O horizon	OHORZN
pH of soil 0-2.5 cm deep	PH1
pH of soil 2.5-12.5 cm deep	PH5

Table 3. CORRELATIONS FOR PHYSICAL CHARACTERISTICS OF FOUR DISPARATE EPIGAEA REPENS CONTAINING SITES (data gathered summer 1991 and 1992 from MM-I, MM-II, Frey and Hongen sites). The top value is the Pearson Correlation Coefficient and bottom value is the probability. Variables are listed in descending order of probability. Because most *E. repens* roots are found in the top 2.5 cm of soil I used pH1 values and not pH5.

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 24

	ERDEN	LX	SLOPEDEG	OHORZN	ASPECT	LITDP	BASDEN	CANHT	CC	SAPDEN	PH1
LX	0.480*	1.000	0.237	-0.194	0.242	-0.128	-0.109	0.030	-0.007	0.242	0.069
	0.018*	0.0	0.265	0.364	0.256	0.552	0.612	0.891	0.974	0.255	0.748
SLOPEDEG	0.458*		1.000	-0.349	0.020	-0.216	-0.112	-0.094	0.220	0.625*	0.133
	0.025*		0.0	0.094	0.926	0.312	0.602	0.662	0.302	0.001*	0.534
OHORZN	-0.383			1.000	0.031	0.257	-0.184	0.140	-0.189	-0.155	-0.210
	0.065			0.0	0.884	0.225	0.389	0.514	0.377	0.469	0.325
ASPECT	0.296				1.000	-0.076	0.177	0.039	0.244	0.114	0.477*
	0.160				0.0	0.723	0.409	0.857	0.250	0.596	0.018*
LITDPT	-0.136					1.000	-0.068	-0.227	-0.321	-0.177	-0.413*
	0.525					0.0	0.752	0.286	0.127	0.408	0.045*
BASDEN	0.113						1.000	0.256	0.096	-0.129	-0.222
	0.600						0.0	0.228	0.655	0.547	0.297
CANHT	-0.065							1.000	0.327	-0.093	-0.100
	0.763							0.0	0.118	0.666	0.641
CC	0.058								1.000	0.255	0.488*
	0.788								0.0	0.229	0.016*
SAPDEN	0.056									1.000	0.340
	0.796									0.0	0.104
PH1	-0.030										1.000
	0.888										0.0

* correlations that are statistically significant

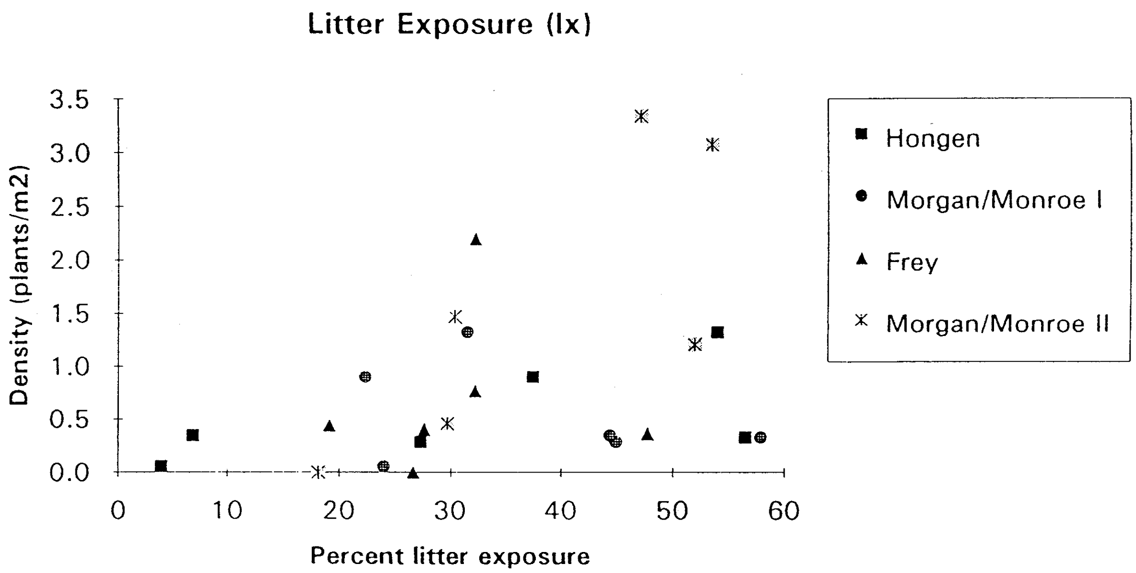


Figure 8. *E. repens* density (plants/m^2) vs. percent liter exposure (lx)

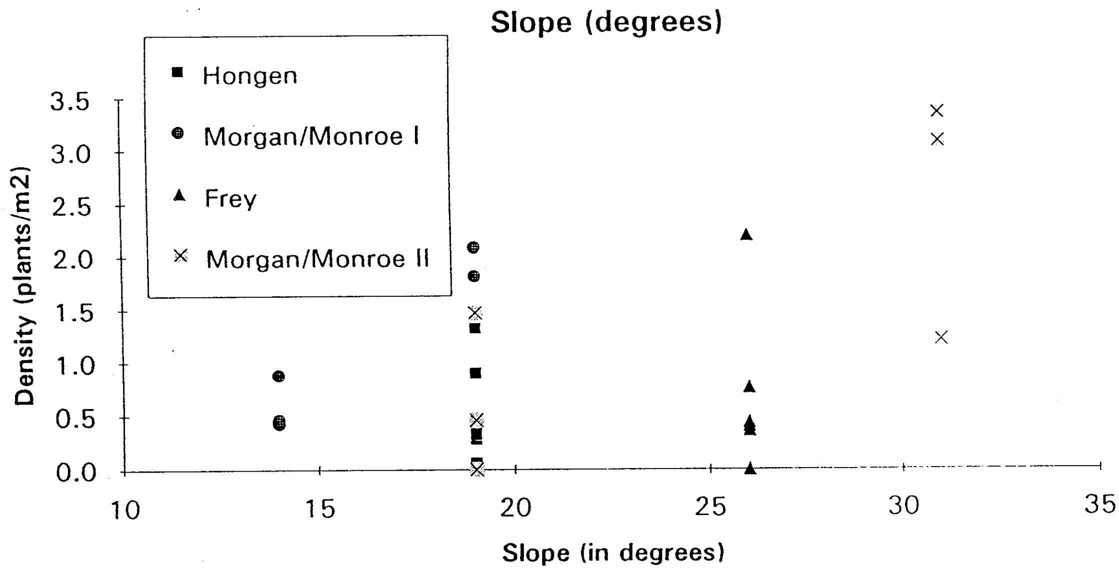


Figure 9. *E. repens* density (plants/m^2) vs. slope (degrees)

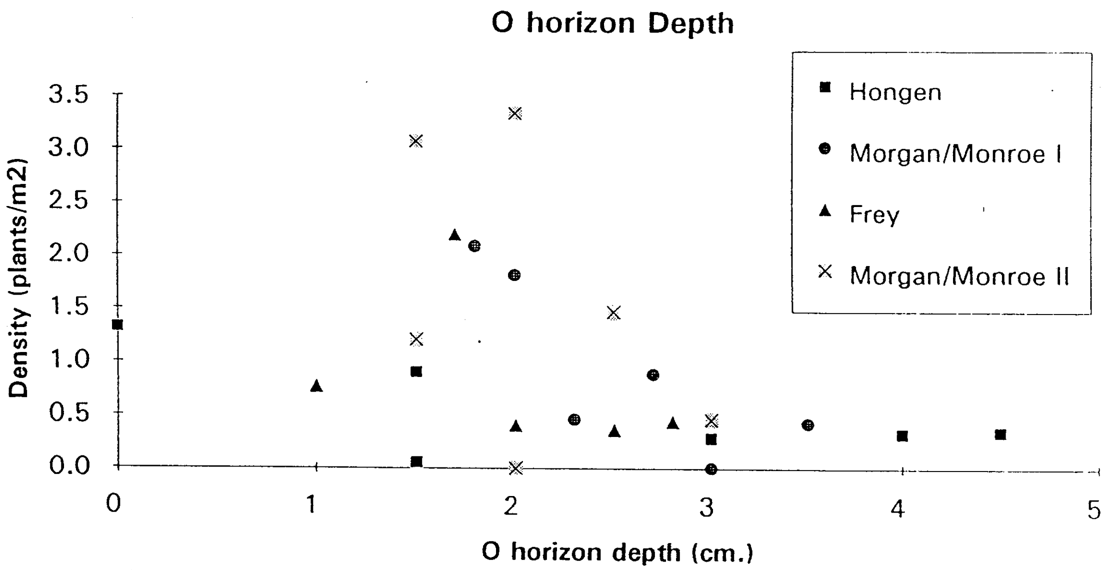


Figure 10. *E. repens* density (plants/m^2) vs. O horizon depth

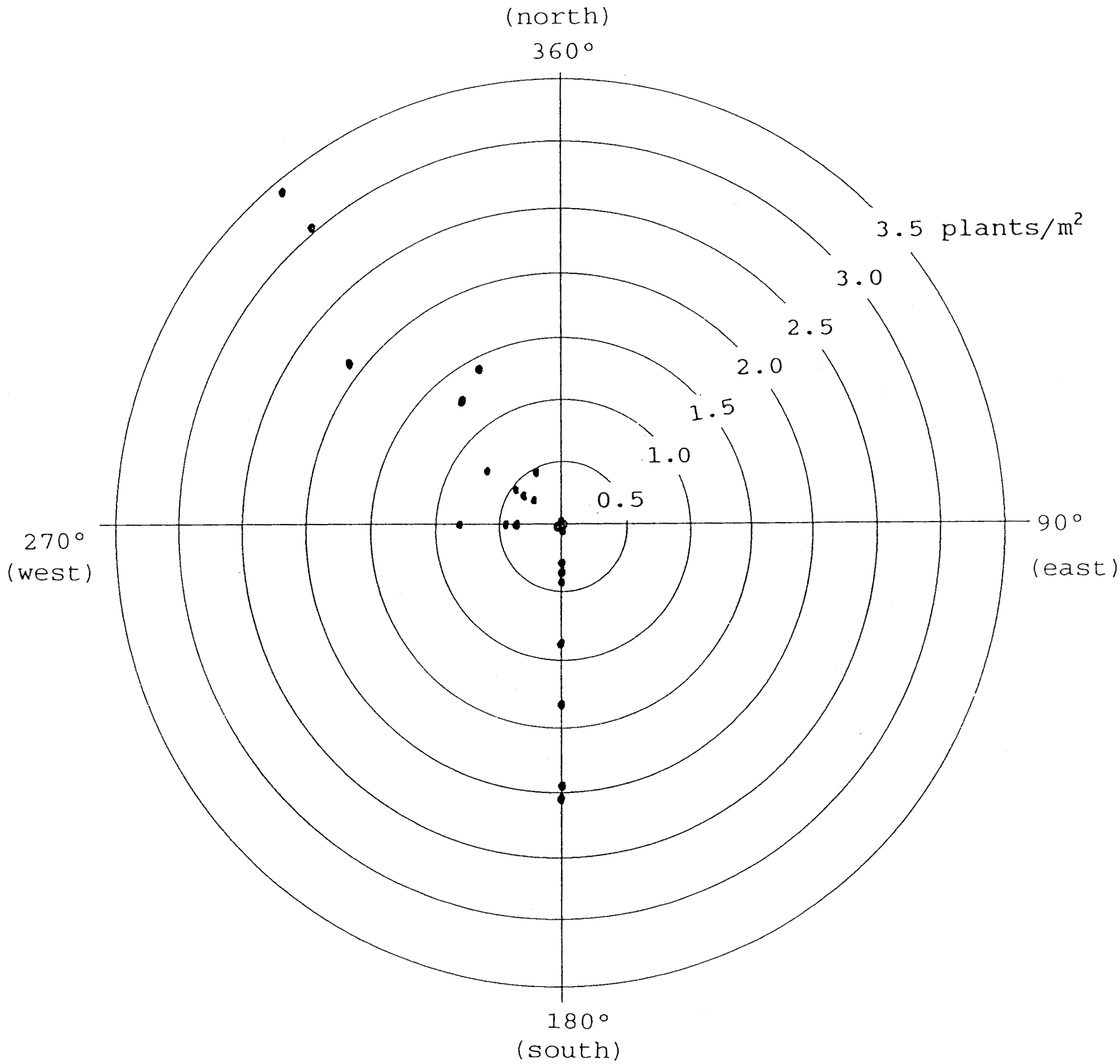


Figure 11. *E. repens* density (plants/m^2) vs. aspect of sites. Concentric circles represent 0.5 plants/m^2. Hongen and MM-I Sites at 180°; MM-I Site at 270°; Frey Site at 300°; and MM-II Sites at 320° and 330°.

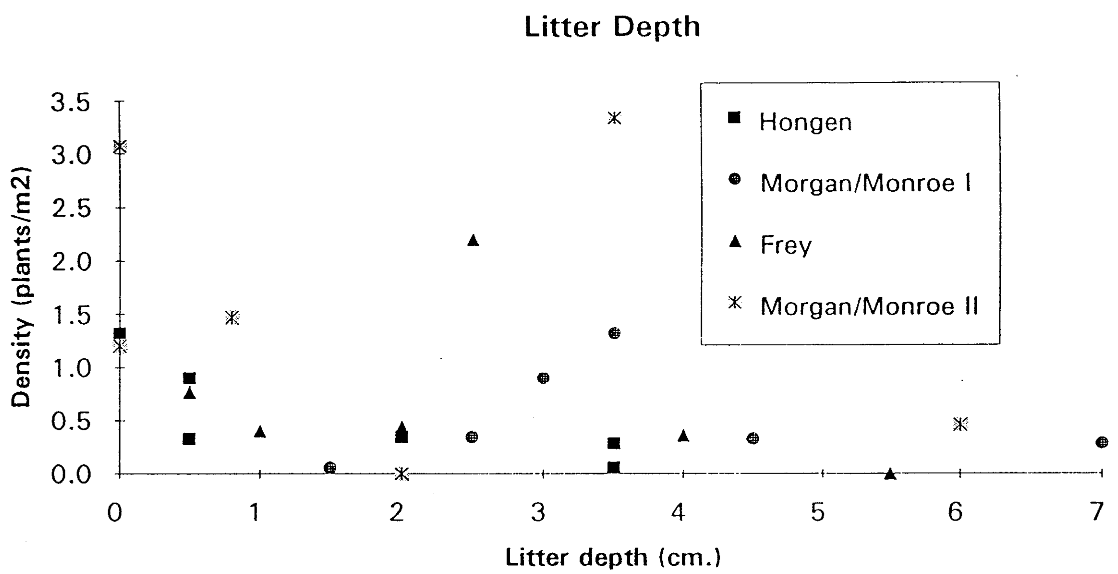


Figure 12. *E. repens* density (plants/m^2) vs. litter depth

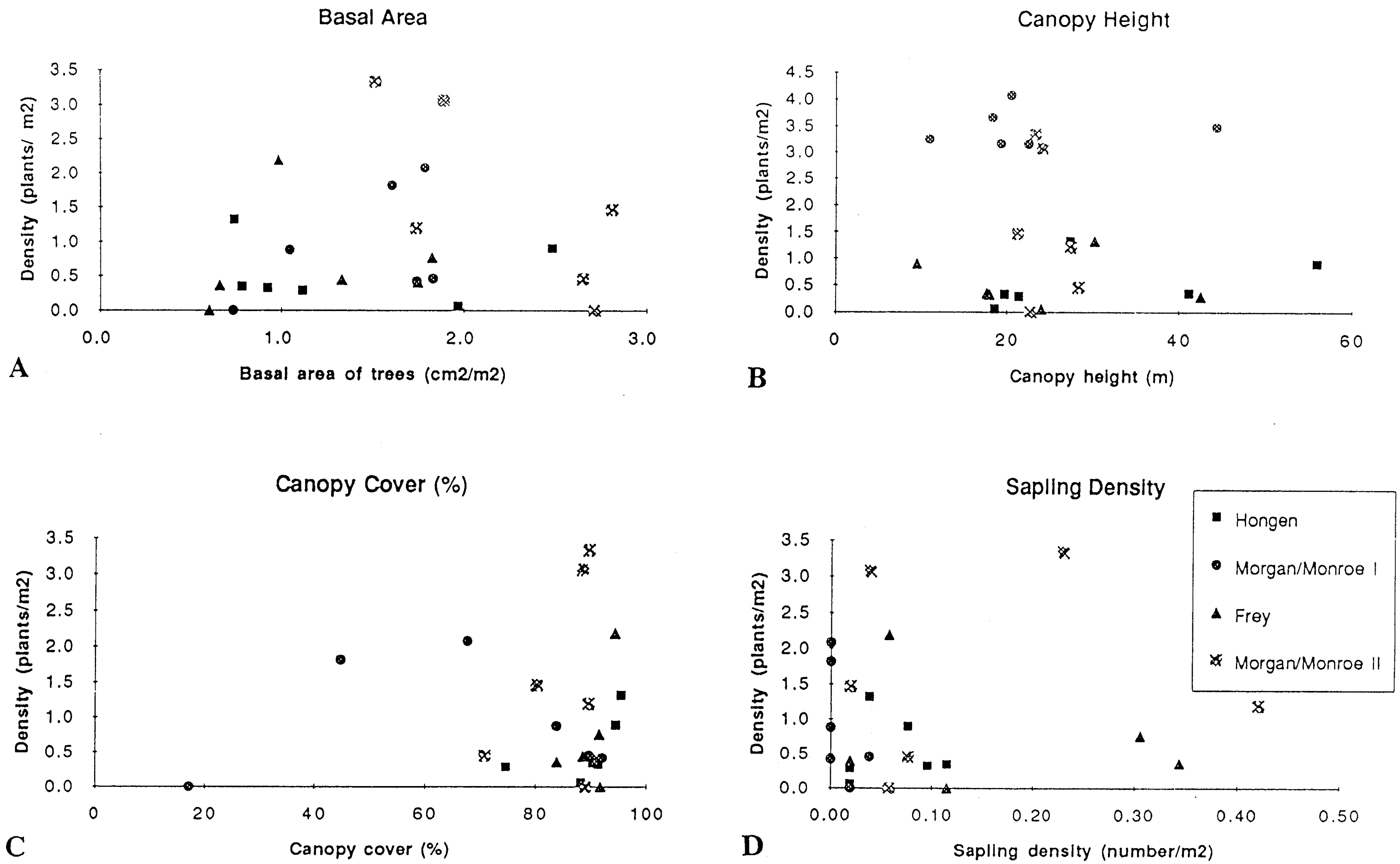
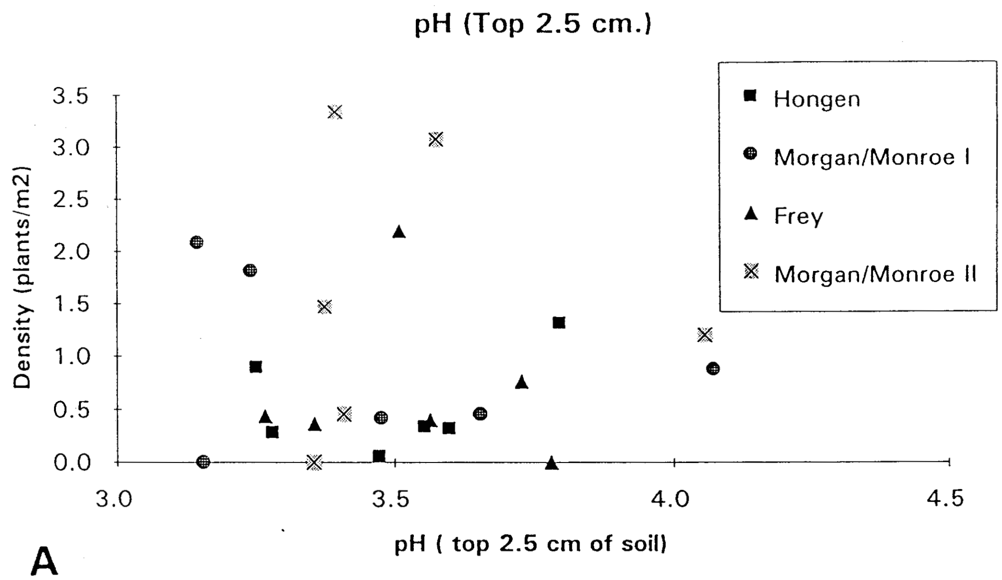


Figure 13. *E. repens* density (plants/m^2) vs. basal area, canopy height, canopy cover, and sapling density



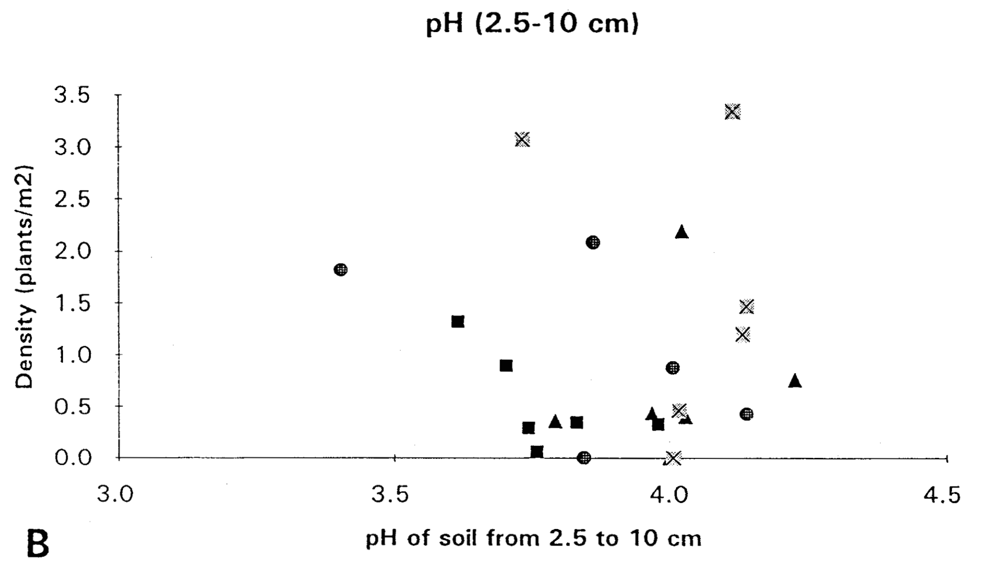


Figure 14. *E. repens* density (plants/m^2) vs. pH of the top 2.5 cm of soil and the soil from 2.5-10 cm

Table 4. Soil characteristics of sites with <u>E. repens</u>

Site	Horizon	Thickness	Hue	Value/Chroma
Frey	A	0.8 - 3.0 cm	10YR	3/1 - 4/3
	B	14.5 - 29.0 cm	10YR	5/4
Hongen	A	0.7 - 4.0 cm	10YR	2/2 - 4/2
	B	7.5 - 32.5 cm	2.5Y	5/4
			10YR	5/4 - 5/6
MM-I	A	1.0 - 2.2 cm	10YR	2/2 - 5/2
	B	11.5 - 37.0 cm	10YR	5/4 - 5/6
MM-II	A	0.5 - 3.5 cm	10YR	3/2 - 4/4
	B	14.0 - 30.0 cm	10YR	5/4 - 5/6

Table 5.

Proportion of sub-plots containing species from the vegetation count of plants < 0.5 m high

SITE	Hongen	Frey	MM-I	M-II	Total
GENUS/SPECIES					
Carex picta	1.00	0.83	0.67	0.83	3.33
Vaccinium pallidum	0.33	1.00	1.00	1.00	3.33
Acer rubrum	0.67	0.50	0.67	0.50	2.34
moss	0.67	0.50	0.33	0.67	2.17
Viburnum acerifolium	0.17	0.83	0.17	0.67	1.84
Smilax rotundifolia	0.33	0.83	0.67	0.00	1.83
Sassafras albidum	0.17	0.67	0.17	0.00	1.01
Quercus prinus	0.00	0.00	0.50	0.17	0.67
Hamamelis virginiana	0.00	0.00	0.00	0.67	0.67
lichen	0.17	0.33	0.00	0.17	0.67
Mitchella repens	0.17	0.17	0.00	0.33	0.67
Quercus rubra	0.00	0.33	0.17	0.17	0.67
Fagus grandifolia	0.17	0.00	0.00	0.33	0.50
Nyssa sylvatica	0.00	0.33	0.17	0.00	0.50
Desmodium rotundifolium	0.33	0.00	0.00	0.00	0.33
Smilacina racemosa	0.17	0.17	0.00	0.00	0.34
Polystichum acrostichoides	0.00	0.00	0.00	0.17	0.17
Desmodium canescens	0.00	0.00	0.00	0.17	0.17
Carya spp.	0.00	0.17	0.00	0.00	0.17
Medeola virginiana	0.00	0.00	0.00	0.17	0.17
Panicum spp.	0.00	0.17	0.00	0.00	0.17
Rubus spp.	0.17	0.00	0.00	0.00	0.17
Solidago spp.	0.00	0.00	0.00	0.17	0.17
Acer saccharinum	0.17	0.00	0.00	0.00	0.17
Trifolium spp.	0.00	0.00	0.17	0.00	0.17
Liriodendron tulipifera	0.00	0.00	0.17	0.00	0.17
unknown	0.17	0.00	0.00	0.00	0.17
Quercus alba	0.17	0.00	0.00	0.00	0.17

Table 6.

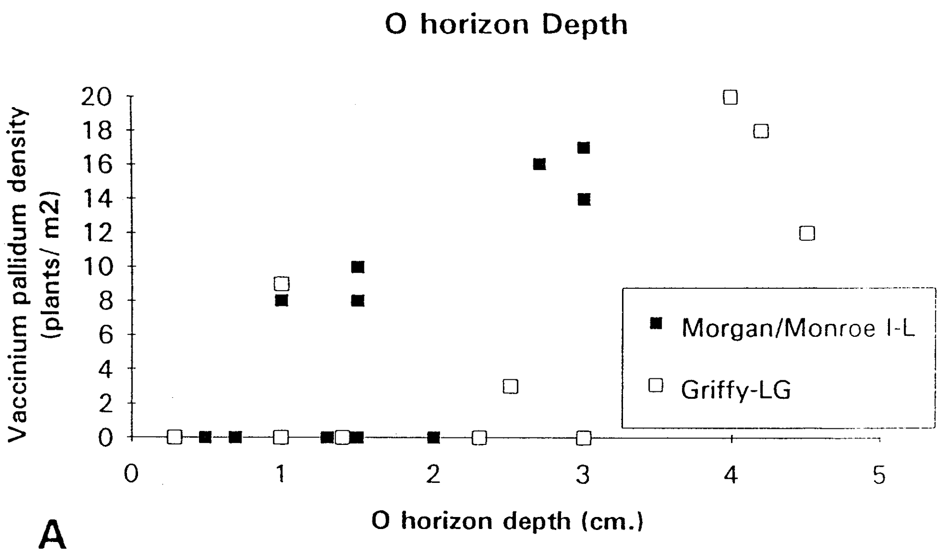
Proportion of sub-plots containing species from the count of trees > 2.5 cm dbh

SITE GENUS/SPECIES	Hongen	Frey	MM-I	MM-II	Total
Acer rubrum	0.33	0.67	1.00	0.83	2.83
Fagus grandifolia	0.83	0.50	0.50	0.33	2.16
Quercus prinus	0.00	0.67	0.00	1.00	1.67
Nyssa sylvatica	0.17	0.50	0.67	0.33	1.67
Amelanchier canadensis	0.17	0.67	0.15	0.50	1.51
Quercus alba	0.67	0.33	0.17	0.00	1.17
Quercus rubra	0.17	0.00	0.50	0.00	0.67
Quercus velutina	0.17	0.00	0.00	0.00	0.17
Hamamelis virginiana	0.00	0.00	0.00	0.17	0.17

Table 7. Average soil pH levels at MM-I site (1993)

plot	pH 0-2.5 cm	pH 2.5-10 cm	vegetation
MM-IA	3.137	3.748	E[1]. and V[2].
MM-IB	3.120	3.695	V. no E.
MM-IC	3.729	NA	no V. or E.
MM-ID	3.611	NA	no V. or E.

1. *E. repens* 2. *V. pallidum*



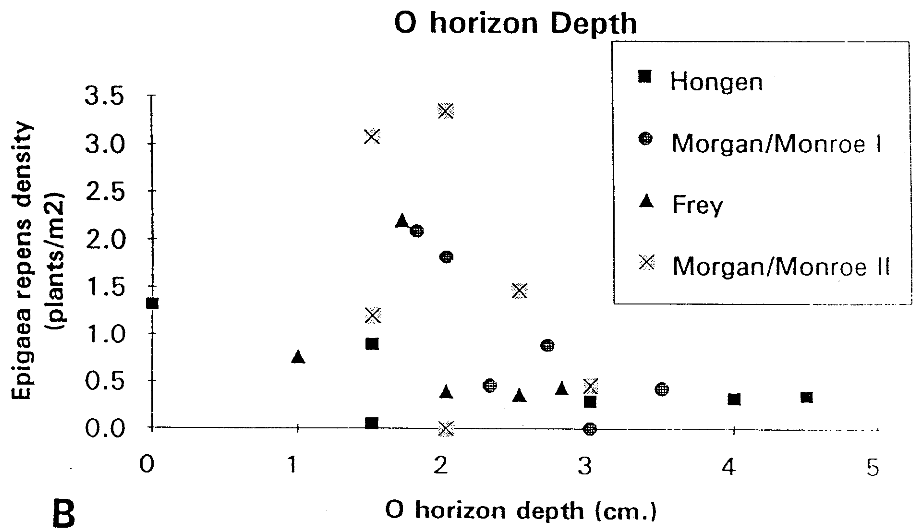


Figure 15. *Vaccinium pallidum* (plants/m^2) versus O horizon (top) and *E. repens* density (plants/m^2) vs. O horizon (bottom).

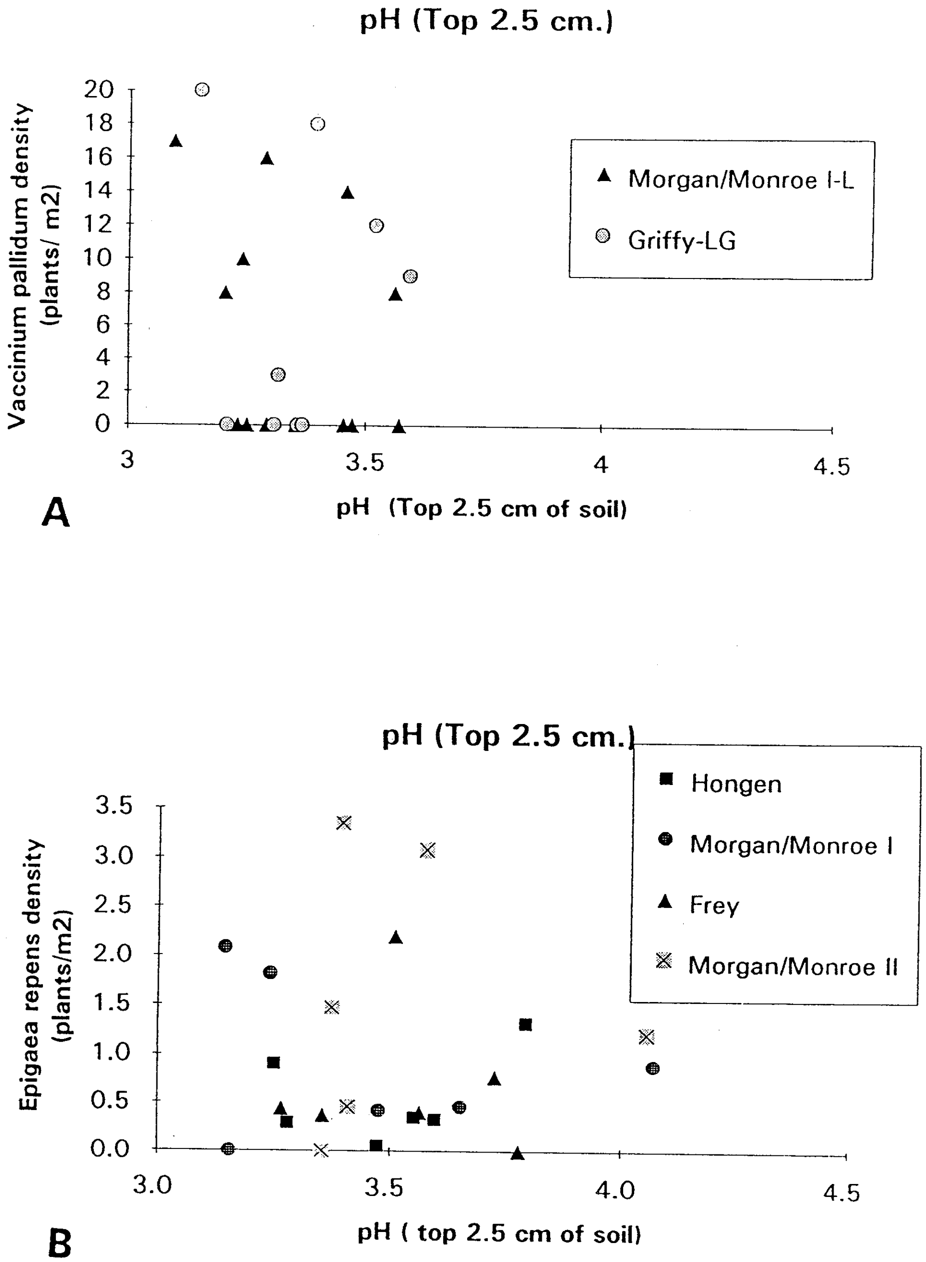


Figure 16. *Vaccinium pallidum* (plants/m^2) versus pH of top 2.5 cm of soil (top) and *E. repens* density (plants/m^2) vs. pH of top 2.5 cm of soil (bottom).

Table 8. Mean *Epigaea repens* flowering 13.5 months after controlled burn

Treatment	N	Mean number of flowers
burn	16	$2.0^{a} \pm 0.75$
buffer	16	$12.6^{ab} \pm 4.10$
control	16	$28.5^{b} \pm 7.63$

$F = 7.06$ df $= 2,45$ $P = 0.002$

Means with different superscripts differ significantly (Tukey's *a posteriori* test)

Table 9. Mean *Epigaea repens* flowering 25.5 months after controlled burn

Treatment	N	Mean number of flowers
burn	16	$7.0^{a} \pm 3.02$
buffer	16	$7.2^{a} \pm 2.71$
control	16	$16.1^{a} \pm 6.11$

$F = 1.52$ df= 2,45 $P = 0.230$

Means with different superscripts differ significantly (Tukey's *a posteriori* test)

Table 10. Mean differences in the number of leaves, stems, and buds before the controlled burn and 17.5 months after the burn

	N	burn	buffer	control	$^{*}F_{2,42}$	P
leaves	45	23.70	33.40	38.07	0.61	0.55
stems	45	8.00	10.27	9.93	0.17	0.85
buds	45	-0.27	1.67	1.07	0.75	0.48

* One-way ANOVA

Table 11. Sex ratios of *E. repens*.

site	male	female	χ^2	d.f.	P
Frey	12	15	0.33	1	> .25
Hongen	17	27	2.27	1	> .10
MM-II	9	15	1.50	1	> .20

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APPENDIX

Sources for the distribution of *Epigaea repens* in North America used to draw map in figure 1.

Alabama

report from Herbarium, Univ. of Alabama, Tuscaloosa

Arkansas

not present; report from Herbarium, Univ. of Arkansas, Fayetteville

Connecticut

report from the G.S. Torrey Herbarium, Univ. of Conn., Storrs and from Herbarium, Harvard University, Cambridge, Mass.

Delaware

report from Herbarium, Delaware State Univ., Dover

Florida

report from Herbarium, Univ. of Florida, Gainsville

Georgia

report form Herbarium, Univ. of Georgia, Athens

Illinois

report from Herbarium, Field Museum of Natural History, Chicago

Iowa

not present; *fide* George Yatskievych, Missouri Botanical Garden, St. Louis

Kentucky

report from Herbarium, Univ. of Kentucky, Lexington

Maine

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Massachusetts

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Minnesota

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Mississippi

no report

Missouri

not present; report from Herbarium, Missouri Botanical Gardens, St. Louis

New Hampshire

report from Herbarium, Univ. of New Hampshire, Durham and report from Herbarium, Harvard, Cambridge, Mass.

New Jersey

report from Chrysler Herbarium at Rutgers University, Piscataway.

New York

report from Herbarium, New York State Museum, Albany

North Carolina

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Ohio

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Pennsylvania

report from Herbarium at the Academy of Natural Sciences, Philadelphia

Rhode Island

report from Herbarium, Harvard University, Cambridge

South Carolina

report from Herbarium, Univ. of South Carolina, Columbia

South Dakota

no report

Tennessee

report from Herbarium, Univ. of Tennessee, Knoxville including records from Vanderbilt Univ. Nashville; two counties in addition from Blanch, 1977

Vermont

report from Pringle Herbarium, Univ. of Vermont, Burlington and Herbarium, Harvard Univ., Cambridge, Mass.

Virginia

report from Herbarium, College of William and Mary, Williamsburg and Harvill, A.M., Jr. et al. 1992. Atlas of the Virginia flora. v. 3. Virginia Botanical Associates, Burkeville, Virginia.

West Virginia

report from Herbarium at West Virginia University, Morgantown

Wisconsin

report from Herbarium at University of Wisconsin at Madison based on specimens and floras there

CANADA

Manitoba

report from Herbarium, Univ. of Manitoba, Winnipeg

New Brunswick

report from the New Brunswick Museum Herbarium and Hinds, Harold R. 1986. The flora of New Brunswick. Fredericton, N.B., Univ. of New Brunswick [check pub]

Newfoundland

report from Ayre Herbarium, Univ. of Newfoundland, St. John's

Nova Scotia

report from Herbarium, Nova Scotia Museum, Halifax

Ontario

report from Herbarium at the Canadian Museum of Nature, Ottawa and Soper, James H. & Margaret L. Heimburger. 1985. Shrubs of Ontario. ROM, Toronto. 495 pp.

Prince Edward Island

report from Herbarium, Univ. of Prince Edward Island, Charlottetown

Quebec
report from Herier Marie-Victorin, Univ. de Montreal, Montreal

Saskatchewan
report from Herbarium, Univ. of Saskatchewan, Saskatoon

GENERAL

Blauch, Doyle Stewart 1977. A taxonomic study of the Ericaceae of the southern Appalachian highlands. Ph.D. thesis, West Virginia University.

Curriculum Vitae
Roger Beckman

Personal

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Education

Graduate:	Master of Library Science Indiana University Bloomington, Indiana 1976
Undergraduate:	Bachelor of Arts Indiana University Bloomington, Indiana 1972

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C401, Introduction to Chemical Information and Sources II, 1st semester 1990/91

Elected Positions:

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